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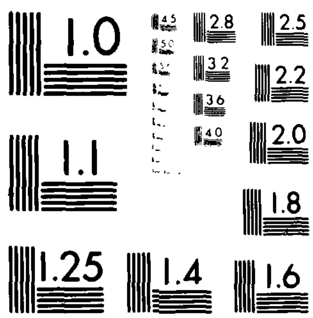

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RESEARCH AND DEVELOPMENT TECHNICAL REPORT
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ELECTROMAGNETIC RADIATION SYSTEM (EMRS) FOR SUSCEPTIBILITY TESTING

Jack Van Arsdale

AMERICAN ELECTRONIC LABORATORIES, INC.
P.O. Box 691
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JUNE 1981

FINAL REPORT

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The Electromagnetic Radiation System (EMRS) is designed to generate electromagnetic energy to produce a constant field strength while scanned automatically in frequency. Design objective was 200 volts per meter from 30 Hz to 40 GHz. This report describes the development of prototype system elements covering the ranges of 30-60 MHz, 1-2.1 GHz, 2.1-4.0 GHz and 12.4-18.0 GHz.

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TABLE OF CONTENTS

1. Introduction

This report describes a prototype Electromagnetic Radiation System (EMRS), developed for the U.S. Army Communications Research and Development Command, Fort Monmouth, New Jersey, under contract DAAB07-76-C-0332.

The report includes a description of the prototype system, a summary of performance test results, problems encountered and solutions, and recommendations for improvements in system performance.

Phase I of the program covered research and investigation to determine the specific requirements for the EMRS and methods for meeting these requirements. The result of the Phase I study was the Design Plan.

The objectives of the Design Plan were as follows:

- Outline the program conducted during concept development
- Summarize the various design approaches considered in Phase I
- Present the final recommended system

The Design Plan also contained a detailed description of the design parameters and characteristics of the system to be constructed, a description of model fabrication, and discussion of the test program to verify performance of the experimental model.

Phase II of the EMRS program was to implement the system described in Phase I and is the subject of this report.

2. OBJECTIVES

The Phase II demonstration EMRS was described Reference (1). The objective of Phase II (hardware phase) was to design, build and test a system which would demonstrate the feasibility of the specifications described in the Phase I Study. Table I lists the system specifications as defined in Reference (2).

For the Phase II Demonstration EMRS, the frequency ranges were restricted to representative bands. This was done to reduce the system hardware requirements.

Table II shows the specification for the Phase II (hardware phase) EMRS.

The objective of Phase II of the EMRS program was to design and/or specify system components that would be integrated into a system which would meet the specification listed in Table II. The components would then be developed or procured and the system would be constructed. When completed, the EMRS Demonstration System would be capable of generating well-controlled, very high electromagnetic field for use in susceptibility testing.

The signals generated would be of precise frequency, narrow bandwidth, and of high purity. FM, AM, and pulse modulation capabilities would be provided.

The system would be capable of both manual and automatic sweeping of the signal frequency across each band at sweep rates as fast as 5 seconds per octave. The system should contain a computer interface to allow for computer control of frequency, power level, and sweep range. The computer interface to the sweep oscillator would be stranded IEEE-488/75 and should control the sweep oscillator functions. Power control interface would be via a seven bit parallel interface.

TABLE I

SYSTEM SPECIFICATION

The following are system specifications for the EMRS as defined by the Electronics Command Development Specification DS-EH-0116A(A) (Reference (2)):

Characteristic	Specification	Reference Paragraph (DS-EH-0116A(A))
Frequency Range (Radiated Output):	10 kHz - 40 GHz	3.3.8
Frequency Range (Non-radiated Output):	30 Hz - 40 GHz	3.3.9
Radiated Field Strength:	.001 - 200 Volts/Meter	3.3.8
Distance from Antenna to Required Field Strength:	3 Meters	3.3.8
Non-radiated Output:	100 watts @ 30 Hz - 50 kHz (Unmodulated) 10 watts @ 50 kHz - 400 MHz (Modulated) 1 watt @ 30 Hz - 40 GHz (Modulated)	3.3.9
Frequency Accuracy of Measuring Unit:	1 part in 10^8	3.3.5
Power Accuracy of Output Indicator:	$\pm$ 2 dB (without antennas) $\pm$ 4 dB (radiated field strength)	3.3.12
Signal Purity:	Harmonic or spurious emission levels 100 dB below fundamental or less than -110 dBm whichever is greater.	3.3.10

TABLE II

PERFORMANCE REQUIREMENTS AND CHARACTERISTICS

1. Frequency Range and Accuracy (Automatic and Manual Tuning)

	Manual	Automatic
30 MHz to 60 MHz	$\pm$ 10 MHz	$\pm$ 15 MHz
1.0 GHz to 2.1 GHz	$\pm$ 10 MHz	$\pm$ 15 MHz
2.1 GHz to 4.0 GHz	$\pm$ 20 MHz	$\pm$ 30 MHz
12.4 GHz to 18.0 GHz	$\pm$ 50 MHz	$\pm$ 70 MHz

2. Scan Rate Limits (Automatic Sweep)

$\leq$ 5 Seconds/Octave

to

> 100 Seconds/Octave

3. Modulation Capabilities

	Deviation	Modulating Freq.
a. FM	$\pm$ 75 MHz *	DC - 200 Hz
*Except $\pm$ 30 MHz in range of 30 MHz to 60 MHz.	$\pm$ 5 MHz	DC - 200 kHz
	$\pm$ 2 MHz	1 MHz - 2 MHz
	% Mod.	
b. External AM:	0 - 100%	DC - 150 kHz

c. Pulse	RT/FT	Pulse Width	Frequency
	50 Nanoseconds	.05μ second	100 Hz to
		5 milliseconds	1 MHz

4. Radiated Output and Level Variation

.001 to 200 volts/meter $\pm$ 3.0 dB (Automatic Swept Mode)

5. Non-radiated Output and Level Variation

10 watts @ 30 to 60 MHz

1 watt @ 1 to 2.1 GHz $\pm$ 3.0 dB (Automatic Swept Mode)

2.1 to 4.0 GHz

12.4 to 18.0 GHz

6. Signal Purity

Spurious and harmonic response 100 dB below the carrier (fo) signal level.

3. SYSTEM DESCRIPTION

3.1 Figure 1 shows a block diagram of the demonstration EMRS for the frequency band 30 to 60 MHz. Figure 2 shows a block diagram for the frequency band 1 to 2.1 GHz. Figure 3 shows the system for the frequency bands 2 to 4 GHz and 12.4 to 18 GHz.

The main components of the system of Figure 1 are a sweep oscillator signal source (1), control unit (2), power amplifier (3), tracking filter (4), antenna subsystem consisting of power splitters (5), two or four conductor striplines (6), 50 ohm loads (7), and a 50 ohm attenuator (8). Directional coupler (9) samples the sweeper output for filter positioning.

The system of Figure 2 is the same as Figure 1 except that the directional coupler (9) is part of the tracking filter.

The main system components in Figure 3 for the 2.1 to 4.0 GHz and 12.4 to 18.0 GHz band are the same as in Figure 2, except that the refocused parabola replaces the stripline radiating system and RF feedback is taken before the antenna by the directional coupler (5) in Figure 3.

3.2 Subsystem Functions

3.2.1 The Sweep Oscillator (1) is the RF signal source for the demonstration EMRS. The signal source can be operated in a cw mode or several sweep modes. Control is provided manually or by remote digital programming. The remote programming mode allows for computer control of oscillator frequency, frequency band and sweep mode.

3.2.2 The EMRS Control Unit (2) provides for control of RF power level and leveling, AM and pulse modulation, RF overload protection, filter power supplies and power switching, and AC power control. A block diagram of the control unit is shown in Figure 4. More detailed information on the EMRS control unit is given in Reference 14.

3.2.3 The Power Amplifier (3) provides power amplification to obtain signal levels sufficiently high to generate the 200 V/m field intensity required by EMRS. For the frequency band 30 to 60 MHz, a solid state 100 watt amplifier is used. For frequencies above 1 GHz, traveling wave tube amplifiers are used.

3.2.4 The Tracking Filter (4) provides tunable narrowband filtering of the amplifier output signal. The filter is designed to track the center frequency of the sweep oscillator in either cw or sweep modes. The filter is mechanically tuned using a servo positioning unit.

3.2.5 The Antenna Subsystem (5), (6), (7), and (8) of Figures 1 and 2, and (6) of Figure 3 transform the RF power from the tracking filter output into the field intensity required to meet the design goals of EMRS. Figures 1 and 2 show a four-section stripline with associated power splitter, 50Ω loads and 50Ω attenuator. The equipment to be radiated forms a ground plane for the stripline and is subjected to E fields normal to its surface. A detailed description of the stripline is given in Section 3.

The refocused parabola shown in Figure 3 is designed to radiate a unit under test at approximately three meters distance. Monitoring of the radiated field intensity is provided by the field probe (7).

3.3 SYSTEM COMPONENTS

3.3.1 RF Sweep Oscillator Subsystem

The EMRS Design Plan, dated May 1977 (Reference 1), established these basic performance criteria for the sweep oscillator subsystem:

a. Four frequency bands covered.

30 to 60 MHz

1 to 2 GHz

2 to 4 GHz

12.4 to 18 GHz

b. Automatic and manual scanning of frequencies within each of the above bands.

c. Output power veriable over a 106 dB dynamic range.

d. Provision for computer control of all important sweep oscillator functions including frequency, sweep mode, and output power level.

e. Modulation capabilities to include:

Amplitude modulation - 0 to 50% with 100 Hz to 10 MHz modulating frequencies.

Frequency modulation - 0 to 10 MHz deviation with 100 Hz to 10 MHz modulating frequencies.

In order to meet these requirements, a survey of available sweep oscillators was made, resulting in the selection of the Hewlett-Packard 8620C mainframe with RF plug-ins; 86222B, 86235A, and 86260A, for the 30 to 60 MHz and 1.0 to 2.1 GHz, 2.1 to 4.0 GHz, and 12.4 to 18.0 GHz bands respectively. A detailed description of the sweep oscillator systems is given in references 6, 7, 8, and 9.

The 86222B plug-in covers the frequency range from 10 MHz to 2.4 GHz. The 86235A covers the range from 1.7 to 4.3 GHz and the 86260A covers the range from 12.0 to 18.0 GHz.

The 8620C with the RF plug-in can be manually or automatically swept over the entire frequency band or any portion thereof. The sweeper RF power output can be varied manually over a 10 dB minimum range. To achieve the 106 dB dynamic range, the EMRS control panel provides an additional 51 db of control. Since the minimum gain of the power amplifiers in EMRS is 30 dB, the system can be operated without the amplifier to give a range of 81 dB. The remaining 25 dB is obtained by switching a fixed 25 dB attenuator in series with the low level system RF output.

Computer control of sweep mode, frequency band, frequency, and remote marker are provided by a built in HP-IB (IEEEE-485/75) interface bus. Remote power level control over a 51 dB range in 1 dB steps is provided by an external 7 bit unencoded input.

The sweep oscillator modulation capabilities depend on the RF plug-in used. Except for FM modulation, the sweeper system modulation capabilities are not adequate. Therefore, external PIN diode modulators are used to meet the requirements.

3.3.2 EMRS Control Unit

3.3.2.1 The EMRS control unit consists of the following:

a. A front panel containing controls and indicators, programmable attenuators, RF and control signal input and output connectors, PIN diode pulse modulator, PIN diode amplitude modulator and leveling loop controller, and leveling loop DC amplifier and filter.

b. Circuit boards containing circuits for control and signal processing.

c. Power supplies to provide power for the programmable attenuators, logic and amplifier circuits, and tracking filters.

3.3.2.2 Panel Features

The EMRS Control Unit front panel is shown in Figure 5. The features of the panel are described below.

1. ALC PROGRAMMABLE ATTENUATOR RF INPUT N CONNECTOR J1.

The RF signal from the tracking filter output is fed back to J1 and used for RF signal leveling. The maximum RF power permitted at J1 is 1 watt average, 100 watts peak, for less that 10 microseconds.

2. VIDEO OUT BNC CONNECTOR J4.

Output is proportional to the ALC RF signal level into J1. Output is also controlled by attenuator switched (7), (9), (11) and (13).

3. VIDEO IN BNC CONNECTOR J3.

The detected ALC RF is the input to J3 which feeds the DC programmable attenuator.

4. ALC PROGRAMMABLE ATTENUATOR RF OUTPUT N CONNECTOR J2.

The RF signal level at J2 with respect to the level at J1 varies from minus 40 to 0 dB in 10 dB steps depending on the setting of the attenuator switches (8), (10) and (12).

5. RF OVERLOAD RESET SWITCH

Resets RF protection circuits when the source of an RF overload has been removed.

6. RF OVERLOAD INDICATOR

Red LED indicator which lights when RF power into J1 exceeds 1 watt or RF power into ALC crystal detector exceeds 100 milliwatts.

7. 1 dB ATTENUATOR SWITCH (S4)

Adds 1 dB of attenuation between J10 and J11 and simultaneously removes 1 dB of attenuation between J3 and J4.

8. 10 dB ATTENUATOR SWITCH (S1)

Adds 10 dB of attenuation between J8 and J9 and subtracts 10 dB between J1 and J2.

9. 2 dB ATTENUATOR SWITCH (S5)

Adds 2 dB of attenuation between J10 and J11 and subtracts 2 dB between J3 and J4.

10. 20 dB ATTENUATOR SWITCH (S2)

Adds 20 dB of attenuation between J8 and J9 and subtracts 20 dB between J1 and J2.

11. 4 dB ATTENUATOR SWITCH (S6)

Adds 4 dB of attenuation between J10 and J11 and subtracts 4 dB between J3 and J4.

12. 40 dB ATTENUATOR SWITCH (S3)

Adds 40 dB of attenuation between J8 and J9 and subtracts 40 dB between J1 and J2.

13. 4 dB ATTENUATOR SWITCH (S7)

Adds 4 dB of attenuation between J10 and J11 and subtracts 4 dB between J3 and J4.

14. UNLEVELED INDICATOR

Yellow LED when lighted indicates that the automatic leveling circuit is not able to level the RF power as selected.

15. RF INPUT TO 0 TO 11 dB PROGRAMMABLE ATTENUATOR N CONNECTOR J10.

RF power from pulse pin diode on ALC pin diode is input here. Maximum power input is 1 watt average, 100 watts peak, for less than 10 microseconds.

16. RF INPUT TO 0 TO 40 (70) dB PROGRAMMABLE ATTENUATOR N CONNECTOR J8

RF power from J11 is input here. Maximum input power is 1 watt average, 100 watts peak for less than 10 microseconds.

17. RF OUTPUT FROM 0 TO 11 dB PROGRAMMABLE ATTENUATOR N CONNECTOR J11.

The RF signal level at J11 with respect to the level at J10 varies from 0 dB to 11 dB in 1 dB steps depending on the selection of switches (7), (9), (11), (13).

18. RF OUTPUT FROM 0 TO 40 dB (OPTIONAL 0 TO 70 dB) PROGRAMMABLE ATTENUATOR N CONNECTOR J9.

The RF signal level at J9 with respect to the level at J8 varies from 0 to 40 dB in 10 dB steps depending on the selection of switches (8), (10), (12).

19. ATTENUATOR PROTECT INPUT BNC CONNECTOR J5.

Input to ALC attenuator protection circuits. DC signal from ALC attenuator RF input level detector is applied here.

20. AC POWER SWITCH

Controls 120 VAC, 60 Hz power to EMRS Control Unit.

21. ALC INPUT BNC CONNECTOR J6

Input to ALC circuits. Accepts signal from DC attenuator output J4.

22. DETECTOR PROTECT INPUT BNC CONNECTOR J7

Input to ALC detector protection circuits. DC signal from ALC detector is applied here.

23. POWER INDICATOR

Green LED is lighted when DC power is applied to filters.

24. FILTER POWER SELECTOR SWITCH

Five-position switch which selects -5 VDC, ±5 VDC low current, and ±15 VDC high current filter power. Positions are: OFF, 30 to 60, 1 to 2, 2 to 4, and 12.4 to 18.

25. REMOTE/LOCAL SELECTOR SWITCH (S8)

Selects either local or remote control of programmable attenuators. When in the LOCAL position, attenuators are controlled by panel switches. In the remote position, control is via remote control connector.

26. RF INPUT TO ALC PIN DIODE SMA CONNECTOR J12

Output of RF sweep oscillator is applied to J12. Maximum RF input power is 2 watts cw.

27. AM MOD INPUT BNC CONNECTOR J14

Amplitude modulation signal is applied to J14.

28. RF OUTPUT FROM ALC PIN DIODE SMA CONNECTOR J15

RF output from J15 varies to compensate for system loss variations.

29. RF POWER LEVEL CONTROL

Controls system RF power level by varying the bias on the ALC pin diode. Clockwise rotation increases RF power out of J15. The system power level is monitored using an external power meter connected at the output of the stripline (see figures 1 and 2) or just before the input to the refocused parabola (see figure 3). Attenuator switches S1 through S7 are used to control

the RF power with respect to the reference level.

30. RF OUTPUT SMA CONNECTOR J13 OF PULSE MODULATION PIN DIODE

Pulsed RF power output varies with pulse modulation signal applied to J17.

31. RF INPUT SMA CONNECTOR J16 OF PULSE MODULATION PIN DIODE

Maximum RF power is 2 watts cw.

32. PULSE MOD INPUT BNC CONNECTOR J17

Pulse modulation signal applied to J17, modulates the bias to the pulse mod pin diode. Input is one TTL load.

3.3.2.3 Control Panel RF Interconnections

Figure 6 shows the RF interconnections for operating the EMRS control panel under normal conditions in any of the four frequency bands. All RF interconnecting cables are RG141 semi-rigid coaxial cables with SMA or N connectors as appropriate. Cables for the DC output from the crystal detectors are RG55 with BNC connectors.

3.3.3 Power Amplifiers

3.3.3.1 30 to 60 MHz Band

The EMRS 30 to 60 MHz band power amplifier is the Electronic Navigation Industries Inc. Model 3100L Broadband Power Solid State Amplifier. The specifications of the 3100L include:

Gain	50 dB $\pm$ 1.5dB 250KHz to 105MHz
Frequency Range	120KHz to 120MHz
Power Output	100 Watts 250KHz to 105MHz

Additional specifications are contained in reference 10. The amplifier can work into any load and from any source impedance without damage.

3.3.3.2 1.0 to 2.1 GHz Band

The EMRS 1.0 to 2.1 GHz Band Power amplifier is a logimetrics A600L traveling wave tube (TWT) amplifier. The specifications of the A600L include:

Gain	40dB
Frequency Range	1.0 to 2.0GHz
Power Output	200 watts
Input/Output	
Impedance	50 ohms

Additional specifications are contained in reference 11.

The A600L contains TWT protection circuitry which senses RF power reflected back into the TWT output. If the reflected power exceeds 50 watts, (nominal) the TWT is automatically shut down.

3.3.3.3 2.1 to 4.0 GHz Band

The EMRS 2.1 to 4.0 GHz band power amplifier is a Logimetrics A600S traveling wave tube (TWT) amplifier. The specifications of the A600S include:

Gain	43dB
Frequency Range	1.0 to 2.0GHz
Power Output	200 watts
Input/Output	
Impedance	50 ohms

3.3.3.4 12.4 to 18 GHz Band

The EMRS 12.4 to 18.0 GHz band power amplifier is a Logimetrics A200u traveling wave tube amplifier. The specifications of the A200u include:

Gain	30 dB
Frequency Range	12.0 to 18.0 GHz
Power Output	10 watts
Input/Output	
Impedance	50 ohms

Additional specifications are contained in reference 13.

3.3.4 EMRS Tunable Bandpass Automatic Tracking Filters

(A detailed description of the filters discussed below is contained in reference 14.)

3.3.4.1 The 30 to 60 MHz band tracking filter is capacitively tuned and provides narrow band filtering of the power amplifier output over the 30 to 60 MHz frequency range. The 3dB bandwidth is 3.5 MHz (nominal). The filter will track the f_o center frequency with manual tuning or automatic sweep rates of 5 seconds per octave maximum.

A frequency to voltage conversion is used to determine the filter position with respect to the signal frequency. The RF frequency is divided

by 100 to be within the range of a frequency (f) to voltage (v) converter. The output of the f to v converter is a dc voltage which is proportional to frequency and is used to provide positioning information to the filter. This technique allows filter tracking for either increasing or decreasing frequencies.

3.3.4.2 The 1.0 to 2.1 GHz band tracking filter is mechanically tuned with stubs and provides narrowband filtering of the TWT amplifier output over the 1.0 to 2.1 GHz frequency range. The filter 3 dB bandwidth is nominally 4% of the center frequency.

The filter will track the f° center frequency with manual tuning or at automatic sweep rates of 5 seconds per octave maximum.

Unlike the 30 to 60 MHz tracking filter, the 1.0 to 2.1 GHz filter position information is obtained using an auxiliary filter. The auxiliary filter is a single stage filter which is gang tuned with the main bandpass filter. The two filters areaarranged so that the 6 dB point on the high frequency skirt of the auxiliary filter is at the center frequency of the main filter passband. The RF power out of the auxiliary filter is detected and compared with the detected unfiltered, leveled power out of the sweeper. The RF power out of the auxiliary filter will increase above the reference level if the sweeper frequency f_s is less than f° of the main filter. If f_s is greater than $f_{\circ}$, the auxiliary filter output will decrease. This changing signal is processed and used to position the main filter center frequency $f_{\circ}$ at the sweeper frequency f_s.

The 1.0 to 2.1 GHz filter tracks increasing frequencies only. If the frequency f_s is manually timed to frequencies below the filter passband, tracking is lost and the filter returns to its low frequency mechanical stop before moving up to f_s.

The maximum RF power into the filter is 200 watts with a 50 ohm load.

3.3.4.3 The 2.1 to 4.0 GHz band tracking filter is essentially the same as the 1.0 to 2.1 GHz filter except for the frequency range. Tracking is achieved in the same way and the maximum power permitted is 200 watts into 50 ohms.

3.3.4.4 The 12.4 to 18.0 GHz band tracking filter operates in essentially the same way as the 1.0 to 2.1 and the 2.1 to 4.0 GHz filters. The maximum power permitted is 10 watts with a 50 ohm load.

3.3.5 <u>Stripline Antenna System</u>

The radiating element for the 30 to 60 MHz band and the 1.0 to 2.1 GHz band is a stripline configuration.

3.3.5.1 Stripline Field Generator

As described in Reference 15, the stripline field generating system consists of stripline transmission line with one of the ground planes removed. To measure susceptibility, the stripline is placed over the equipment under test (EUT) as shown in Figure 7 so that the EUT fills all or part of the opening in the stripline. Conductive panels are then slid into position such that the entire opening in the stripline is filled. In this way, the EUT surface and the panels become a ground plane for the stripline.

When the stripline is energized by an RF signal generator, electric and magnetic fields are generated between the center conductor and the ground plane which induce currents on the ground plane which includes the surface of the EUT (Figure 8). It is these currents which are the mechanism by which energy is coupled into the equipment.

3.3.5.1.1 Design Considerations

The stripline configuration was determined based upon the required electrical characteristics and practical problems of implementing the system.

The stripline was designed for a characteristic impedance of fifty ohms which is a function of the geometry of the stripline as defined below:

$$Z_o = \frac{1}{\sqrt{\varepsilon}} \quad \frac{94.15}{\left(\frac{w/b}{1-t/b} + \frac{C_f'}{.08856}\right)} \qquad (1)$$

where:

ε = relative dielectric constant of the material between the center conductor and ground planes

w = width of the center conductor

b = separation between ground planes

t = thickness of the center conductor

C_f' = fringe capacitance

Because the surface of the EUT provides a portion of the ground plane, the spacing between the center conductor and the ground plane must be great enough to accommodate any obstacles which protrude above the surface. It has been determined that the majority of the protrusions do not exceed 1.5 inches. Therefore, the center conductor to ground plane spacing was chosen as 1.5 inches. The center conductor thickness is .020 inches. Foam is used to maintain a uniform spacing between the existing ground plane and center conductor, and dielectric standoffs are used between the center conductor and the EUT surface. Therefore the dielectric constant is approximately 1.0. With these parameters known, the center conductor width is determined, from equation (1), to be 3.96 inches.

Since it is necessary to measure equipment as large as 3 x 3 x 5 feet, the relative field strength as a function of transverse displacement from the stripline center conductor must be determined. Since the field strength generated is to be within ± 3 dB of a nominal value, the fields between adjacent lines may be 6 dB lower than the maximum field strength which occurs at the centerline of the center conductor. It was determined experimantally that at a transverse displacement of .8w, where w is the width of the center conductor, the fields are down 11 dB. Since the adjacent lines are fed in phase, fields between lines will add resulting in a field strength which is 5 dB below the maximum. It was also determined that at a displacement of .66 w, the field strength is down 6 dB relative to the maximum. Therefore, n adjacent striplines will generate electromagnetic fields which are within ± 3 dB of the desired nominal value over a width given by:

$$[2(.66) + (2)(.88)(n-1)]w = \text{width of area covered} \tag{2}$$

where:

n = number of lines

w = center conductor width

For the EMRS stripline, where $w = 3.96$ inches, 6 adjacent lines will be required to illuminate a three (3) foot width.

As discussed previously, the spacing between the center conductor and the EUT surface will be maintained by dielectric standoffs. Since the equipment being tested will vary, the configuration of the standoffs must be changeable so that they can be placed so as to not interfere with any protrusion above the equipment surface. This was accomplished by placing a dielectric sheet between the center conductor and the ground plane. This sheet contains numerous holes into which the standoffs can be placed as required. The dielectric sheet also adds rigidity to the center conductor. Figure 9 is a photograph of the two conductor stripline systems, showing the dielectric sheet and standoffs.

3.3.5.1.2 Description of Exploratory Development Model

An exploratory development model has been built as shown in Figure 9. The model shown in this figure consists of two (2) adjacent striplines which are thirty-six (36) inches long excluding the coax to stripline transitions. The input and output connectors are SMA "female" connectors. The two striplines are fed by a 3 dB hybrid such that the lines are fed in phase. The output ports are terminated with fifty ohm loads.

The photograph shows the sliding doors in the open position with five (5) dielectric spacers snapped into position.

In addition to the two line model shown in Figure 9, an identical two line model was built. When joined with the other two line model, this forms a four line model, as shown in Figure 10. Equation (2) shows that an object as large as 12 x 36 inches can be measured with the twolline model and an object as large as 33 x 36 inches can be measured with the four line model.

These models are both operational from DC to 2 GHz in the principal TEM mode.

3.3.5.1.3 Equivalence with Radiated Techniques

The field generating system developed on the EMRS program is to be used as an electromagnetic radiation source for testing the susceptibility characteristics of military communication-electronics equipments and systems. Since an electromagnetic radiated field has electric fields which are parallel to the surface of the equipment being tested and the electromagnetic fields generated by the stripline has electric fields which are perpendicular to the surface of the equipment being tested, the question arises as to the equivalence of these techniques.

A theoretical analysis of this equivalence was performed as aprt of Phase I of this program and is included as Appendix 3 of Reference 15. The conclusion of this analysis was that a 2:1 relationship exists. That is, if it is required to measure the susceptibility characteristics of a piece of equipment to a radiated field of E_o volts per meter, the same characteristics will be determined by generating a field of $2E_o$ volts per meter between the stripline center conductor and the surface of the equipment being tested.

As described in Reference 16, this relationship was determined experimentally from 1.0 to 2.0 GHz using a model of the stripline and a box with a slot cut in it to simulate a discontinuity in the surface of a piece of test equipment. A plane wave of RF energy was radiated towards the box at normal

incidence and the amount of power received was determined. The stripline was then placed over the box and the amount of power coupled into the box, with the same field strength present as was present at the box for the radiated case, was measured. The average ratio of these powers over the 1-2 GHz band was 6.4:1 (Figure 11) or a current ratio of 2.5:1. The discrepancy between the theoretical ratio (2.0) and the experimental value (2.5) is within the limit of error of the measurement.

3.3.5.4 Power Requirements

One of the primary advantages of the stripline method over existing methods used for measuring radiated susceptibility is that high field strengths can be generated with relatively low input powers.

The power required per line to generate a given field strength is derived in Appendix 1 of Reference 16 and is given by the following equation:

$$P = \frac{(Ed)^2}{Z}$$

where:

E = field intensity to be generated (V/m)

d = spacing between the stripline center conductor and ground plane (meters)

Z = characteristic impedance of the stripline (ohms)

Figure 12 is a plot of the field strengths generated as a function of input power. This figure includes a curve indicating the nominal field intensity generated and the peak field intensity generated assuming a VSWR of 1:1, and the nominal field intensity generated assuming a VSWR of 2:1. The VSWR on the final system is less than 1.5:1 across the entire frequency band.

It can be seen from Figure 12 that a nominal field intensity of 400 Volts/meter (equivalent to a 200 V/m radiated field) requires 9.2 watts per line. It should be noted that when using equation (3) to determine required power that the field intensity used in the equation should be 3 dB higher than the nominal value which is to be produced. This is a result of the design method whereby the peak field generated is 3 dB higher than the required nominal value.

3.3.5.5 Field Strength Verification

The magnitude of the fields generated using the stripline method can be determined by rewriting equation (3) such that field strength is a function of input power as given below:

$$E = \sqrt{\frac{ZP}{d^2}} \qquad (4)$$

Since the power is known, the field strength can be determined. It should be noted that the field intensity resulting from solution of equation (4) is the peak field intensity. The nominal field intensity is found by multiplying the results of equation (4) by .707.

3.3.6 Refocused Parabolas

The field generating system for the 2.1 to 4 GHz and 12.4 to 18.0 GHz bands consists of refocused parabolas. The advantage of refocusing is that far field radiation patterns can be produced in the near field. This is an important feature because it allows the use of large aperture, high gain antennas in a limited area. The greater the gain, the less power required to produce a given field intensity. The drawback of the increased aperture is the narrow beamwidths produced. Because the area illuminated within ± 3 dB of a nominal field intensity is that area contained within the 6 dB beamwidth of the antenna, as the beamwidth decreases, the area illuminated decreases. However, with the costs of high power generators at higher frequencies, it has been determined that the increased gain offsets the disadvantage of decreased area coverage.

3.3.6.1 Description of Exploratory Development Models

Two parabolic reflectors have been built and tested. The reflectors are thirty-six inches in diameter and are fed by linearly polarized horns. The reflectors are designed to operate over two bands, 2-4 GHz and 12-18 GHz. The 2-4 GHz reflector is fed by an AEL Model H-1498 horn which has had the input connector changed from SMA to TNC "female" to increase power handling capability. The 12-18 GHz reflector is fed by an AEL Model H-6100 which has had the internal polarizer removed since circular polarization is not required.

3.3.6.2 Experimental Results

The refocused parabolas were measured at a range of three (3) meters to determine their radiation characteristics in free space. In addition, the 2-4 GHz reflector has been measured inside a room to determine the effects of random reflections on the fields produced.

3.3.6.3 Free Space Data

Radiation patterns and gain were measured on each of the antennas over their respective frequency bands in a free space environment. Figures 13 and 14 are typical radiation patterns for the 2-4 GHz and 12-18 GHz reflectors respectively and Figures 15 and 16 are the measured gains. This data illustrates the beamwidth-gain tradeoff discussed in the previous section. For example, at 3 GHz, the reflector has an electrical aperture of 9.2λ, a 6 dB beamwidth of 9.1 degrees and a gain of 24.2 dBi. At 15 GHz, the reflector diameter is 45.8λ, the 6 dB beamwidth is 1.9 degrees and the gain is 37.65 dBi. Therefore, the thirty-six inch reflector will illuminate a 1.6 foot diameter, circular section within $\pm$3 dB at a range of 3 meters at 3 GHz and a .33 foot section at 15 GHz. Approximately 20 times as much area is illuminated with the smaller electrical aperture. Conversely, approximately 20 times as much power is required to generate the same field intensity with the smaller aperture than is required for the larger aperture because of the difference in antenna gain.

3.3.6.4 Antenna Performance in a Non-Absorptive Room

To determine the effect of placing the antenna in a non-free-space environment, the 2-4 GHz reflector was measured at 2 GHz in a "standard" room. The fields were then measured with a field probe to determine the field distribution as a function of transverse displacement from boresight. This measurement was made in two inch increments left and right of boresight and above and below boresight. The antenna boresight was five (5) feet above the floor and approximately five (5) feet below the ceiling. There were cinder-block walls five (5) feet to the right and twenty (20) feet to the left of boresight (referenced looking toward the antenna). The results of these measurements are plotted in Figures 17 and 18. For comparison, the field distribution in free space is also plotted. It can be seen from this data that there is not a significant difference in the field distribution for the antenna in free space and in the enclosed room. However, it cannot be concluded that this will be the case when the system is deployed in a shielded enclosure. The room in which the referenced measurements were made contained few reflective surfaces and cannot be considered representative of a shielded enclosure. For this reason, a field probe has been developed to measure the field distribution in the shielded enclosure. If the enclosure perturbs the fields such that there is a non-uniform distribution, it may be necessary to line the enclosure with microwave absorber to minimize reflections. The extent to which the enclosure must be absorptively lined must be determined after the system has been installed and tested in the enclosure.

3.3.7 Power Requirements

The power required to generate a given field strength with the refocused parabolas is a function of the antenna gain. The gain of the 2-4 GHz and 12-18 GHz parabolas has been plotted in Figures 19 and 20. With the gain known, the required power is then determined by the following equation:

$$P_T = \frac{(ER)^2}{30\ G_T} \tag{5}$$

where:

E = peak field intensity to be generated (volts/meter)

R = distance from source to point at which field is to exist (meters)

G_T = gain of the refocused parabola (power ratio)

Equation 5 is derived in Appendix 2 of Reference 16. The power required is plotted in Figures 19 and 20 as a function of frequency for the 2-4 GHz and 12-18 GHz bands respectively.

To demonstrate the use of these curves, the following example is given. What is the power required to generate a 5 volt/meter field? To determine the power required, first determine the appropriate value of the coefficient "A". For this case, A = -3. Now find 5 volts/meter on the y-axis of the curve and move horizontally across until it intersects the 3 GHz line. Reading the horizontal axis indicates that the power required is $5.65 \times 10^{(A+1)}$. Since A = -3, the power required is $5.65\ (10^{-2})$ watts. Therefore, at 3 GHz, 56.5 milliwatts into the 2-4 GHz parabola will create a nominal 5 volt/meter field three meters away from the parabola. It should be noted that the peak field intensity is 3 dB greater than nominal in this case 7.07 volts/meter.

3.2.4 Field Strength Verification

There are two methods which can be used to determine the field intensity being generated. If the radiation characteristics of the antenna in the shielded enclosure can be assumed to be the same as in free space, the field

intensity can be determined directly from equation (5) when the input power is known. If the fields are not well behaved in the shielded enclosure, a field probe can be used to determine the distribution as well as the intensity of the fields. The field intensity is determined by measuring the power received by the probe and applying the following equation:

$$E = (.229)\ (f)\sqrt{\frac{P_R}{G_R}}$$

where:

f = frequency (MHz)

P_R = received power (watts)

G_R = gain of the field probe (power ratio)

This equation is derived in Appendix 7 of Reference 15. The gain of the 2-4 GHz probe and the 12-18 GHz probe is plotted in Figures 21 and 22 respectively.

4. TESTS PERFORMED

4.1 General

The complete EMRS system, except for the antenna subsystem, is rack-mounted as shown in Figure 23. The rack was placed outside the shielded test enclosure and interfaced to the radiating antennas through RF fittings located in the enclosure wall. RF feedback from inside the shielded enclosure was routed through RF wall fittings to the receiving and monitoring equipment located outside of the enclosure.

Tests were performed to verify the performance characteristics given in Table 2.

Tests performed in each band included:

1. Frequency accuracy tests.
2. Modulation capabilities tests.
3. Radiated output and level variation tests.
4. Non-radiated output and level variation tests.
5. Scan rate limits tests.
6. Signal purity tests.

Detailed test procedures for performing these tests are described in Reference (2)

4.2 Test Set-up

4.2.1 For the 30 to 60 MHz and 1.0 to 2.1 GHz band, the test set-up shown in Figure 24 was used to check frequency accuracy, modulation capabilities, non-radiated power output and level variations, and scan rate limits.

For the 2.1 to 4.0 GHz and the 12.4 to 18.0 GHz bands, Figure 25 shows the set-up for the same tests.

4.2.2 Radiated output power and level variations for the 30 to 60 MHz and 1.0 to 2.1 GHz band were determined using the test set-up shown in Figure 26.

Similar tests were for the 2.1 to 4.0 GHz and 12.4 to 18.0 GHz using the set-up of Figure 27.

4.2.3 Signal purity for the 30 to 60 MHz band was checked using the test set-up shown in Figure 28. Figures 29 and 30 show the set-up for the 1 to 2.1 GHz and 2.1 to 4.0 GHz bands respectively.

5. RESULTS

Table III shows the results of testing of the EMRS system using the test procedures described in Reference (1) and are compared to the specified values from Table II. A minus sign marks the test results that do not substantially meet the specified values. A plus sign indicates results that substantially exceed the specified values.

TABLE III

PERFORMANCE TEST DATA, 30 - 60 MHz DATA SHEET NO. 1

	Test Description	Specified Values	Measured Values
	FREQUENCY ACCURACY, CW		
	CW Pointer to 30 MHz	20-40 MHz	30.06 MHz
	CW Pointer to 45 MHz	35-55 MHz	40.13 MHz
	CW Pointer to 60 MHz	50-70 MHz	60.11 MHz
	Full Sweep, Manual Control, CCW	5-35 MHz	22.9 MHz
	Full Sweep, Manual Control, CW	2385-2415 MHz	2403 MHz
	MODULATING CAPABILITIES		
	Amplitude Modulation:		
	Per cent Modulation Index	0-100%	0-100%
+	AM Frequency Response	DC-150 kHz	70 Hz-1.15 MHz
	AM Response Variation within Modulation Band	Not specified	4.5 dB
	Frequency Modulation:		
	Low Frequency Deviation (10 Hz)	$\pm$ 30 MHz	$\pm$ 20 MHz
	High Frequency Deviation (900 kHz)	$\geq \pm$ 5 MHz	$\pm$ 5 MHz
	Pulse Modulation:		
-	Rise Time of Detected Pulse with 5 nanoseconds (nS) Input Pulse Rise Time	50 nS max.	400 nS
-	Fall Time of Detected Pulse with 5 nS Input Pulse Fall Time	50 nS max.	210 nS
-	Minimum Usable Input Pulse Width	0.05 uS	2.0 uS
+	Maximum Usable Input Pulse Repetition Rate	1 MHz	2 MHz
	RADIATED OUTPUT AND LEVEL VARIATION		
	Minimum Output	0.0010 V/M	0.0015 V/M
	Maximum Output	200 V/M	200 V/M
	Swept Power Level Variation	$\pm$ 3 dB	$\pm$ 2 dB

Performance Test Data, 30 - 60 MHz (continued) Data Sheet No. 1 (cont'd)

	Test Description	Spe[illegible]ed Values	Measured Values
	NON-RADIATED OUTPUT AND LEVEL VARIATION		
	Minimum Output	10 watts	10 watts
+	Variation with Amplitude Modulation	± 3 dB	± 2 dB
+	Variation with Frequency Modulation	± 3 dB	± 1 dB
	Variation with Pulse Modulation	± 3 dB	± 3 dB *
	SCAN RATE LIMITS		
+	Maximum	>100 sec/octave	110 sec/octave
+	Minimum	≤ 5 sec/octave	4.1 sec/octave
	SIGNAL PURITY		
	Power Output, Fundamental (Po)	Not specified	100 watts (50 dBm)
+	2nd Harmonic, dB below Po	100 min.	125 min.
+	3rd Harmonic, dB below Po	100 min.	128 min.
+	4th Harmonic, dB below Po	100 min.	128 min.
+	5th Harmonic, dB below Po	100 min.	128 min.

* Providing that duty cycle is greater than 50%.

PERFORMANCE TEST DATA, 1.0 - 2.1 GHz — DATA SHEET NO. 2

	Test Description	Specified Values	Measured Values
	FREQUENCY ACCURACY, CW		
+	CW Pointer to 1.0 GHz	990-1010 MHz	995 MHz
+	CW Pointer to 1.5 GHz	1490-1510 MHz	1495 MHz
+	CW Pointer to 2.1 GHz	2090-2110 MHz	2099 MHz
	Full Sweep, Manual Control, CCW	5-35 MHz	22.9 MHz
	Full Sweep, Manual Control, CW	2385-2415 MHz	2403 MHz
	MODULATING CAPABILITIES		
	Amplitude Modulation:		
	Per cent Modulation Index	0-100%	0-100%
+	AM Frequency Response	DC-150 kHz	70 Hz-1.15 MHz
	Frequency Modulation:		
	Low Frequency Deviation (10 Hz)	$\pm$ 75 MHz	$\pm$ 75 MHz
	High Frequency Deviation (900 kHz)	$\pm$ 5 MHz	$\pm$ 5 MHz
	Pulse Modulation:		
+	Rise Time of Detected Pulse with 5 nS Input Pulse Rise Time	50 nS max.	20 nS
+	Fall Time of Detected Pulse with 5 nS Input Pulse Fall Time	50 nS max.	8 nS
-	Minimum Usable Input Pulse Width	0.05 uS	0.10 uS
+	Maximum Usable Input Pulse Repetition Rate	1 MHz	2 MHz
	RADIATED OUTPUT AND LEVEL VARIATION		
	Minimum Output	0.0010 V/M	0.0015 V/M
	Maximum Output	200 V/M	200 V/M
	Swept Power Level Variation	$\pm$ 3 dB	$\pm$ 3 dB
	NON-RADIATED OUTPUT AND LEVEL VARIATION		
	Minimum Output	1 Watt	1 Watt
+	Variation with Amplitude Modulation	$\pm$ 3 dB	$\pm$ 2 dB
+	Variation with Frequency Modulation	$\pm$ 3 dB	$\pm$ 1 dB
	Variation with Pulse Modulation	$\pm$ 3 dB	$\pm$ 3 dB *

*Providing that the duty cycle is greater than 50%

Performance Test Data, 1.0 - 2.1 GHz (continued)   Data Sheet No. 2 (cont'd)

Test Description	Specified Values	Measured Values
SCAN RATE LIMITS		
Maximum	100 sec/octave	112 sec/octave
Minimum	_ 5 sec/octave	5.0 sec/octave
SIGNAL PURITY		
Power Output, Fundamental (Po)	Not specified	100 watts
+ 2nd Harmonic, dB below Po	100 min.	108 min.
+ 3rd Harmonic, dB below Po	100 min.	110 min.
+ 4th Harmonic, dB below Po	100 min.	110 min.
+ 5th Harmonic, dB below Po	100 min.	110 min.

PERFORMANCE TEST DATA, 2.1 - 4.0 GHz DATA SHEET No. 3

	Test Description	Specified Values	Measured Values
	FREQUENCY ACCURACY, CW		
+	CW Pointer to 2.1 GHz	2080-2120 MHz	2095 MHz
+	CW Pointer to 3.0 GHz	2980-3020 MHz	3009 MHz
+	CW Pointer to 4.0 GHz	3980-4020 MHz	4017 MHz
	Full Sweep, Manual Control, CCW	2080-2120 MHz	2095 MHz
	Full Sweep, Manual Control, CW	4270-4330 MHz	4299 MHz
	MODULATING CAPABILITIES		
	Amplitude Modulation:		
	Per cent Modulation Index	0-100%	0-100%
+	AM Frequency Response	DC-150 kHz	45 Hz-2.0 MHz
	Frequency Modulation:		
	Low Frequency Deviation (10 Hz)	± 75 MHz	± 75 MHz
	High Frequency Deviation (900 kHz)	± 5 MHz	± 5 MHz
	Pulse Modulation:		
-	Rise Time of Detected Pulse with 5 nS Input Pulse Rise Time	50 nS max.	180 nS
-	Fall Time of Detected Pulse with 5 nS Input Pulse Fall Time	50 nS max.	80 nS
-	Minimum Usable Input Pulse Width	0.05 uS	5.0 uS
-	Maximum Usable Input Pulse Repetition Rate	1 MHz	200 kHz
	RADIATED OUTPUT AND LEVEL VARIATION		
	Minimum Output	0.0010 V/M	0.0010 V/M
	Maximum Output	200 V/M	200 V/M
	Swept Power Level Variation	± 3 dB	± 3 dB
	NON-RADIATED OUTPUT AND LEVEL VARIATION		
	Minimum Output	1 watt	50 watts
	Variation with Amplitude Modulation	± 3 dB	± 3 dB
	Variation with Frequency Modulation	± 3 dB	± 3 dB
	Variation with Pulse Modulation	± 3 dB	± 3 dB *

* Providing that the duty cycle is greater than 50%

Performance Test Data, 2.0 - 4.0 GHz (continued) Data Sheet No. 3 (cont'd)

Test Description	Specified Values	Measured Values
SCAN RATE LIMITS		
Maximum	>100 sec/octave	105 sec/octave
Minimum	≤ 5 sec/octave	5 sec/octave
SIGNAL PURITY		
Power Output, Fundamental (Po)	Not specified	100 watts
2nd Harmonic, dB below Po	100 min.	100 min.
3rd Harmonic, dB below Po	100 min.	100 min.
4th Harmonic, dB below Po	100 min.	100 min.
5th Harmonic, dB below Po	100 min.	100 min.

PERFORMANCE TEST DATA, 12 - 18 GHz — DATA SHEET NO. 4

	Test Description	Specified Value	Measured Values
	FREQUENCY ACCURACY, CW		
	CW Pointer to 12.0 GHz	11950-12050 MHz	11970 MHz
	CW Pointer to 15.2 GHz	15150-15250 MHz	15163 MHz
	CW Pointer to 18.0 GHz	17950-18050 MHz	17953 MHz
	Full Sweep, Manual Control, CCW	11930-12070 MHz	11970 MHz
	Full Sweep, Manual Control, CW	17930-18070 MHz	17965 MHz
	MODULATING CAPABILITIES		
	Amplitude Modulation:		
-	Per cent Modulation Index	0 - 100%	0 - 50% for 70 Hz - 150 kHz 0 - 100% for signals over 150 kHz
	Frequency Modulation:		
+	Low Frequency Deviation (200 Hz)	± 75 MHz min.	± 80 MHz min.
	High Frequency Deviation (200 kHz)	± 5 MHz min.	± 5 MHz min.
	Pulse Modulation:		
+	Rise Time of Detected Pulse with 5 nS Input Pulse Rise Time	50 nS max.	30 nS
-	Fall Time of Detected Pulse with 5 nS Input Pulse Fall Time	50 nS max.	70 nS
-	Minimum Usable Input Pulse Width	50 nS	100 nS
+	Maximum Usable Input Pulse Repetition Rate	1 MHz	2 MHz
	RADIATED OUTPUT AND LEVEL VARIATION		
-	Minimum Output	0.001 V/M	0.004 V/M, 12.4 GHz 0.007 V/M, 18 GHz
-	Maximum Output	200 V/M	100 V/M, 12.4 GHz

Performance Test Data, 12 - 18 GHz (continued)   Data Sheet No. 4 (cont'd)

	Test Description	Specified Values	Measured Values
			160 V/M, 18 GHz
	Swept Power Level Variation	± 3 dB	± 3 dB
	NON-RADIATED OUTPUT AND LEVEL VARIATION		
	Minimum Output	1 watt	1 watt
+	Variation with Amplitude Modulation	± 3 dB	± 0.5 dB
+	Variation with Frequency Modulation	± 3 dB	± 0.5 dB
+	Variation with Pulse Modulation	± 3 dB	± 0.5 dB *
	SCAN RATE LIMITS		
+	Maximum	>100 sec/octave	207.5 sec/octave
+	Minimum	≤5 sec/octave	3.1 sec/octave

* Providing that the duty cycle is greater than 50%

6. PROBLEMS ENCOUNTERED AND SOLUTIONS

During the development of the EMRS, problems were encountered which required either changes in the system design or operating procedures in order to meet the requirements of Reference 1. Problems encountered generally involved equipment malfunctions or performance degradation, and/or the incompatibility of available system components with the EMRS design concept.

6.1 Amplifiers

The ENI-3100 solid state amplifier used in the 30 to 60 MHz band performed according to specifications. However, it was found that the traveling wave tube amplifiers used in the remaining bands degraded with time and use. Both maximum saturated power output and small signal gain decreased substantially with time. The worst condition occurred with the Logimetrics A200U TWT (12.4 to 18.00 Hz). In initial tests, tube gasing decreased the gain and saturated power output to levels below the manufacturers specifications.

The amplifier was returned to the manufacturer for a tube replacement. Subsequent test showed adequate performance.

6.2 Filters

Problems encountered with the narrowband tracking filters are discussed below.

6.2.1 Susceptibility to High VSWR

The filter cavities were damaged by arcing at high power when a high VSWR occurred between the output of the TWT amplifier and the filter input. The high VSWR was caused by dynamic tracking errors and retrace mismatch.

The tracking error occurred when the sweep rate of the sweep oscillator exceeded the maximum tracking rate of the filter. This caused the filter center frequency to lag the sweeper frequency which eventually moved out of the passband of the filter. When the RF frequency is outside of the passband, high reflection occurs and the VSWR increases. To avoid this condition, the

system should be operated at low power (10 dBm) until proper tracking rate is determined.

Filter input mismatch also occurred during retrace of the sweep oscillator. The control circuits of the tracking filter are so designed that tracking is only provided for increasing frequencies (except for the 30 - 60 MHz Band). Whenever the filter reaches its upper frequency limit or when the sweeper retraces, the filter will automatically return to its low frequency limit. This return is not synchronous with the sweeper retrace. Therefore, the sweeper frequency moves out of the filter passband. High reflection and high VSWR results. If the filter is operating with high input power, very high standing wave fields will occur in the filter. The result is arcing and the resulting damage to the filter cavity plating. To avoid this condition, the power amplifier should be set to Standby during retrace.

6.2.2 Excessive Dynamic VSWR

During normal filter tracking at nominal rates, the tracking filters had a tendency to tune in discrete steps. As the sweep oscillator frequency increased smoothly, the tracking filter would lag momentarily and then jump to the proper tuning position. The result of this lag is to cause a momentary out-of-band reflection back into the amplifier. At high power levels, the reflected power can momentarily exceed the limit of the TWT amplifier output protection circuits. This causes the TWT output to automatically disconnect. The system RF power, therefore, drops to zero.

This problem is not encountered in the 30 to 60 MHz band because the power amplifier has a solid state output section which will work into any unmatched condition.

The lag in the filter response to an increase in the RF frequency was

corrected by adjusting the sensitivity of the filter detection circuits. This allowed the filter to respond to a change in sweeper frequency before the frequency moved out of the filter passband.

6.2.3 Mechanical Malfunctions

A mechanical malfunction occurred which caused filter tuning and alignment to be affected adversely. The L, S, and Ku band filters used multiple section, stub-tuned filters to achieve the flat passband and sharp skirt roll off. To maintain the passband across the tuning range of the filter, the sections must be gang-tuned.

The mechanical tracking of the tuning stubs in each section must be precisely maintained if good filter characteristics are to be obtained across the tuning range.

During operation of filters, the gear drives had a tendency to slip on the stub shaft and cause mechanical misalignment. To correct this problem, the filters were returned to the manufacturer where the gears were remounted and pinned to the shaft.

6.3 RF Power Leveling

Leveling of RF power originally used detected RF feedback applied to the external leveling input to the RF sweeper. This configuration provided leveling by varying the RF power from the sweeper so that at the point where the field is sensed, the RF signal is maintained relatively constant. This approach worked very well when filtering of the RF signal was not required. However, when using a tracking filter in the system, the filter requires a low level RF signal of 0 dBm $\pm$ 1 dB in order to track a changing frequency. To obtain this $\pm$ 1 dB signal level accuracy, the sweeper must be operated in the internal leveling mode. This requires that the leveling function be obtained using an external PIN diode between the internally-leveled sweeper

output and the rest of the EMRS. This allowed the sweeper to provide a stable RF level to the tracking filter while the external PIN diode provides for leveling of the system RF power.

Since an external PIN diode was already used in the system for fast AM and pulse modulation, it was decided that the same PIN diode could be used for the leveling function.

The single PIN diode was now being driven by three different signals; the ALC leveling signal, the fast AM signal, and the pulse modulation signal. System specification requires that leveling of the RF power be provided during AM and pulse modulation operation. When this was attempted, the AM and leveling drive circuits and the pulse modulation and leveling circuits interacted adversely.

When very low frequency AM signals were used, the leveling circuits sensed the slowly changing RF power as a signal to be leveled. The effect was to cut off the AM modulation at the 100 Hz bandwidth of the leveling amplifier. The resulting AM passband was then approximately 100 Hz to 2 MHz. To correct the low frequency limitation on AM bandwidth, a frequency compensation network was added to cancel out the AM modulation effect in the leveling circuits. This extended the AM bandwidth to DC.

The interaction of the pulse modulation driver and the leveling circuit was indicated by a deterioration in the pulse rise and fall time and minimum pulse width. Since the driver of the ALC circuits and the pulse modulator were summed at the control input to the PIN diode, the low impedance ALC amplifier output caused excessive loading on the pulse modulator driver. To eliminate this interaction, it was decided to incorporate a separate PIN diode in the RF signal path to provide pulse modulation. This approach worked adequately.

An additional problem encountered with the leveling function when

pulse modulation is used concerns the duty cycle of the pulsed RF. Leveling of the RF power is obtained by detecting the RF signal at the point where leveling is required. The detected signal is amplified and compared with a reference level set by the RF power control. The resulting DC level is used to bias the PIN diode so that the RF level remains constant. However, if the RF power is pulse modulated, it is turned off for a portion of a cycle. During this off-time, the ALC senses low RF power and attempts to increase the RF power by reducing the DC bias on the ALC pin diode. Since the instantaneous RF power is zero, the ALC circuit removes all bias from the PIN diode, making its attenuation a minimum equal to its quiescent insertion loss. When the ON portion of the RF cycle occurs following the OFF cycle, it goes to its maximum level until the ALC circuits respond and bias the PIN diode to higher attenuation.

This overshoot in the RF power has the undesirable effects of producing a poorly leveled signal and possibly damaging system components.

The severity of the problem increases as the pulse duty cycle decreases below 50%. To overcome this problem, it is required that the ALC reference level obtained when the RF power is on be sampled and held during the time the RF power is off. This was accomplished by designing a sample-and-hold capability into the leveling amplifier circuit. The sample-and-hold gates are driven by the pulse modulation signal. Whenever the RF is pulsed ON, the ALC acts normally and stores the ALC level on a capacitor. When RF is turned OFF, the ALC loop is opened and the ALC level applied to the PIN diode is determined by the charge stored on the Sample and Hold capacitor. Hence, during the time that the RF is off, there is very little change in the leveling signal applied to the PIN diode. When RF power comes on again, only a very small adjustment in the leveling signal is made by the ALC circuits.

6.4 RF Overload Protection Circuits

In the EMRS system, the leveling circuit is required to smooth out system power level variations of as much as 10 dB. This leveling is accomplished by varying the RF power transmitted to the input of the power amplifier. This is done using a PIN diode in series with the RF signal. To be effective over this 10 dB range, the PIN diode RF attenuation should vary from near zero at the minimum power level to a maximum at the highest power level. The attenuation of the PIN diode, when the RF power is at the high end of its variation, is obtained by detecting the RF power and using the detected signal to bias the PIN diode toward higher attenuation. This technique works well under normal system operation. However, if the biasing drive to the PIN diode is lost because of a break in the feedback loop while the PIN diode is providing maximum attenuation, the system RF power level will jump to its maximum. When this occurs, the maximum power level limits of some system components will be exceeded. In that event, burn out or loss of calibration of system components can occur.

To prevent this from happening, overload protection circuits were designed and incorporated into the system.

The most sensitive system components to be protected were the programmable attenuator used in the ALC feedback loop and the ALC crystal detector. The protection circuits were designed to sense the power levels into these components. If the power levels approach the maximum limits, threshold circuits are activated providing a maximum biasing signal to the pulse modulation PIN diode. This causes the pulse PIN diode attenuation to go to maximum (approximately 40 dB) and thus attenuating the RF power to safe levels. The protection circuits latch in the safe mode and hold the pulse PIN diode at maximum attenuation. When the RF overload condition is removed, the overload protection circuits can be reset using the control panel mounted reset switch.

7. CONCLUSION AND RECOMMENDATIONS FOR SYSTEM IMPROVEMENT

7.1 AM Modulation.

The EMRS test report showed that the AM low frequency response at the 3 dB point was limited to approximately 70 Hz. This condition was caused by limitations of the automatic leveling control circuit (ALC) bandwidth. When the AM frequency is low enough to be in the pass band of the ALC (approximately 100 Hz), the ALC interprets the AM as a varying signal level, effectively levels it and cancels the modulation.

Subsequent to the tests reported in the EMRS test report, the AM response was improved by incorporating an AM low frequency compensation circuit. The compensation circuit is a low pass amplifier which samples the AM signal and develops a correction signal that is sent to the ALC circuit. This effectively cancels out variation in the ALC levels due to AM modulation and allows for leveled AM modulation frequencies down to DC.

7.2 Pulse Modulation.

Pulse modulation characteristics do not entirely meet the rise time, fall time and pulse width requirements. Degree of compliance depends on the RF frequency band.

The response of the pulse modulator system with the EMRS operating in a leveled mode is affected by variables such as RF output power, power level control settings, and programmable attenuator settings, all of which interact to some extent to affect the pulse modulator response characteristics. In addition, the incorporation of a sample-and-hold circuit, to prevent a severe leading edge overshoot during pulse modulation, introduces delay and dampened response time of the ALC circuit which, in turn, reduces the efficiency of the pulse modulator system.

During the course of the test and fabrication program, necessary design modifications and additional circuits were installed to overcome certain pulse

modulation behavioral discrepancies. Although the overall characteristics and behavioral qualities of the pulse modulation system were improved, certain minor deficiencies such as reduced rise time and fall time were introduced as a direct result.

It is therefore concluded that an overall system design review and study analysis would be necessary to arrive at recommendations to correct these existing deficiencies.

7.3 Minimum Radiated Output.

The design requirement for a minimum of 1.0 millivolts per meter of leveled RF field was not achievable. This was due to insufficient sensitivity of the present state-of-the-art broadband crystal detectors used in automatic leveling circuits. At a field intensity of 1.0 millivolt/meter, the corresponding RF power is below the levels required to achieve leveling.

Several possible methods were considered to improve the dynamic range of RF field levels. A dynamic range from 1.0 millivolt/meter to 200 volts/meter is equivalent to 106 decibels. The EMRS, as it stands now, is capable of a 51 dB range, thus having a control range which is 55 dB short of the specified range.

The most feasible method, which would overcome part of the 55 dB range limitation, would be the use of an RF preamplifier. The preamplifier would amplify the RF feedback signal prior to its detection by the ALC crystal diode. Broadband preamplifiers currently available are limited in gain to approximately 25 dB, which would not completely solve the problem.

7.4 Maximum Radiated Output, 2.1 - 4.0 GHz.

The maximum leveled field intensity of 200 volts/meter in the 2.1 to 4.0 GHz band was not obtained at all frequencies. This was caused by insufficient

power output from the power amplifier to overcome system losses. The reduced power output from the amplifier is believed due to tube aging and possible tube gassing.

It is recommended that, in future systems of this type, a 400 watt power amplifier be incorporated to allow for power degradation due to aging.

7.5 Maximum Radiated Output, 12.4 - 18 GHz.

The maximum field intensity of 200 volts/meter was not achieved in the 12.4 to 18 GHz band. Investigations showed two main reasons for reduced output field intensity. These were insufficient RF drive to the TWT amplifier (due to excessive RF attenuation in the control/interface panel and associated RF cables), and reduced maximum RF output power of the TWT amplifier below the levels specified by the manufacturer. The latter was attributed to a gassy traveling wave tube.

It is recommended that a 12.4 - 18.0 GHz intermediate power line amplifier be incorporated to boost the level of drive signal to the TWT amplifier. The required amplification would take place between the RF output of the control/interface panel and the TWT amplifier input. It is also recommended that a final TWT amplifier, having a 100 watt output capability, be substituted for the 10 watt unit now is use. This additional power is needed to compensate for long term aging of the traveling wave tube resulting in reduced output power.

7.6 Additional Recommendations for Improved System Performance.

7.6.1 Noise Suppression.

Because of the very low RF and DC signal levels present in the ALC detection circuits, they are very susceptible to low frequency noise caused by power line radiation or ground loop conduction.

To suppress these noise components, a low-cost audio interference suppressor should be incorporated in the system as a pre-filter for the ALC

crystal detectors. The filter should preferably be broadband to cover RF frequencies from 30 MHz to 18.0 GHz.

7.6.2 Tracking Filter Performance.

The present tracking filter circuit provides for filter movement in only one direction, from low to high frequencies. This prevents an operator from searching (up and down) around a frequency of interest. The filters also require a fixed RF sense level input. This condition precludes the use of the ALC circuits built into the sweep oscillator.

It is recommended that the filter tracking circuits be examined for possible changes that would overcome the above limitations.

7.6.3 Protection Circuits.

The EMRS control unit levels the system RF power by biasing the ALC PIN diode to the required attenuation level. If the control unit power is turned off while system RF power is still on, leveling control is lost and the RF power can rise to undesired levels.

It is recommended that interlock circuits be developed to prevent power turn-off of the ALC circuits unless RF power is also removed.

7.6.4 Addition of Modulation Meter.

To more conveniently monitor AM modulation characteristics, a panel mounted meter that would indicate per cent modulation would be desirable.

7.6.5 Improved Feedback System.

The present method for obtaining RF feedback, for leveling of the radiated field, is to employ a field probe and RF detector. The field probe is mounted at a distance of three meters from the radiating parabolic antenna. The antenna and field probe are generally located in a shielded enclosure with the antenna at a distance of 1 to 3 meters from the enclosure walls. This configuration requires a 6 meter RF cable to be run from the field probe to the

enclosure wall and then to the EMRS control panel. Depending on the RF frequency, the losses in this feedback cable can attenuate the RF feedback signal sufficiently to render it too small to be used by the ALC circuits.

To overcome this RF loss, the crystal detector could be mounted directly on the field probe. DC feedback to the leveling circuits would then be brought out via low-frequency, low-loss, twisted shielded wire to the ALC circuits. Such a configuration could improve the dynamic range by as much as 10 dB, depending on the frequency and length of the RF cables previously used.

The effect of this change on other system requirements should be examined before changes are incorporated.

7.6.6 Beam Scanning.

The refocused parabola radiates a spot size at 3 meters that is approximately 12 inches in diameter for the 2.1 to 4.0 GHz band and four inches for the 12.4 to 18.0 GHz band. For a unit under test with dimensions larger than these spot sizes, it is not possible to illuminate the entire surface with a fixed position antenna.

To permit complete RF coverage of the unit, it is recommended that the antenna be mounted on a pedestal which will allow independent vertical and horizontal scanning of the beam over the unit surface.

Moving the antenna over a raster-type scan pattern could be accomplished either manually or automatically, using a servo motor. For manual scanning, potentiometers driven with the horizontal and vertical axes would be used to convert antenna position to voltages. These voltages would provide antenna position information.

An automatic scanning mechanism would use servo motors to position the antenna. Positioning signals for the motors would be obtained from circuitry designed to provide various scanning modes. Precise raster-type scans, sector scans, manual scans, and others could be programmed into the motor drive circuitry.

7.6.7 Protection of Tracking Filters

The tracking filters used in the EMRS system can be damaged when subjected to high VSWR at high power levels. To prevent this it is recommended that circulators be used to terminate both the RF input and RF output of each filter.

7.6.8 Retrace Blanking Circuits

The EMRS filters require RF blanking during retrace. Since during retrace, the sweeper retraces very rapidly, the filter cannot follow it. This causes the sweeper frequency to fall outside of the filter passband causing high VSWR to be presented to the TWT amplifier, shutting it down.

To prevent TWT shutdown, RF blanking must be used when the tracking filters are driven by the TWT during retrace.

The problem with using retrace blanking is that in the single sweep mode, RF power does not come on until the sweeper is triggered again. Hence, during retrace the filter returns to its low end mechanical stop and stays there, since there is no RF to move it. This is fine as long as the sweeper beginning frequency corresponds to the filter mechanical stop. If a sweeper start frequency above the filter stop is being used, when the external sweep trigger is pushed, the sweeper will begin sweeping at the higher frequency. The filter will be off tuned and TWT shutdown will occur.

A possible solution to this problem would be to let the sweeper run unblanked and provide blanking using the EMRS PIN diodes. In this mode, RF blanking would be provided for retrace and for the time it takes the filter to move from its lower mechanical limit to the sweeper beginning frequency. Since the filter is designed to track at 5 sec/octave, and the slowest retrace takes 2 sec, then a total of 7.0 secs of blanking would be required.

If external blanking of the RF to the TWT is performed using the leading edge of the sweeper blanking pulse as a trigger and using the duration of the blanking obtained to energize a timer, the timer could be set for a duration of 7 secs minimum.

An alternative approach would be to set a blanking one-shot with the leading edge of the sweeper blanking pulse and reset the one-shot with the leading edge of the up gate from each filter control logic circuit (See figure 31).

7.6.9 Limitations During Operation in Shielded Enclosure

The field generating system developed by AEL to measure the susceptibility of electronics-communications equipment to electromagnetic energy satisfies most of the requirements of Electronics Command Development Specification No. DS-EH-0116A(A). (However, the stripline method makes use of the equipment under test as part of the field generating system and therefore the equipment being measured is not three meters from the field generating source). The EMRS system offers an improved capability over existing susceptibility measurement methods as discussed below.

One of the important advantages of the stripline method is that it significantly increases susceptibility measurement capabilities at low frequencies. The stripline method provides a broadband, compact system which produces well defined fields which are confined to a known area, thus eliminating problems of radiation hazards to personnel performing the test. The stripline method is also advantageous in that high field intensities can be generated with relatively low input powers. It has been shown, both theoretically and experimentally, that this method of measuring "radiated" susceptibility is equivalent to methods using standard radiating techniques. However, an additional effort may be worhtwhile to more conclusively demonstrate this equivalence by developing a more precise measurement method to eliminate some of the sources of error and to make this measurement with various sizes and shapes of apertures.

The refocused parabolas which comprise the 2-40 GHz portion of the EMRS system are still subject to some of the same limitations as existing techniques, but offer an improved capability in terms of the power required to generate a given field intensity. The major drawback which may exist for the reflector portion of the system is the effect of reflections from the shielded enclosure. As stated before, measurements should be made over the entire frequency range to determine the magnitude of these effects. If it is determined that reflections are a problem, lining the enclosure with microwave absorber, (in effect building an anechoic chamber inside the shielded enclosure) will result in a good measurement environment which will greatly reduce measurement uncertainty.

It is recommended that an effort be made to produce the free space field distribution in the shielded enclosure. This will significantly reduce the calibration effect and increase the measurement certainty. Measurement certainty is necessary to establish confidence that the equipment being measured is being subjected to the specified field intensities. Measurement uncertainty is one of the primary drawbacks of existing techniques.

SECTION 8

ILLUSTRATIONS

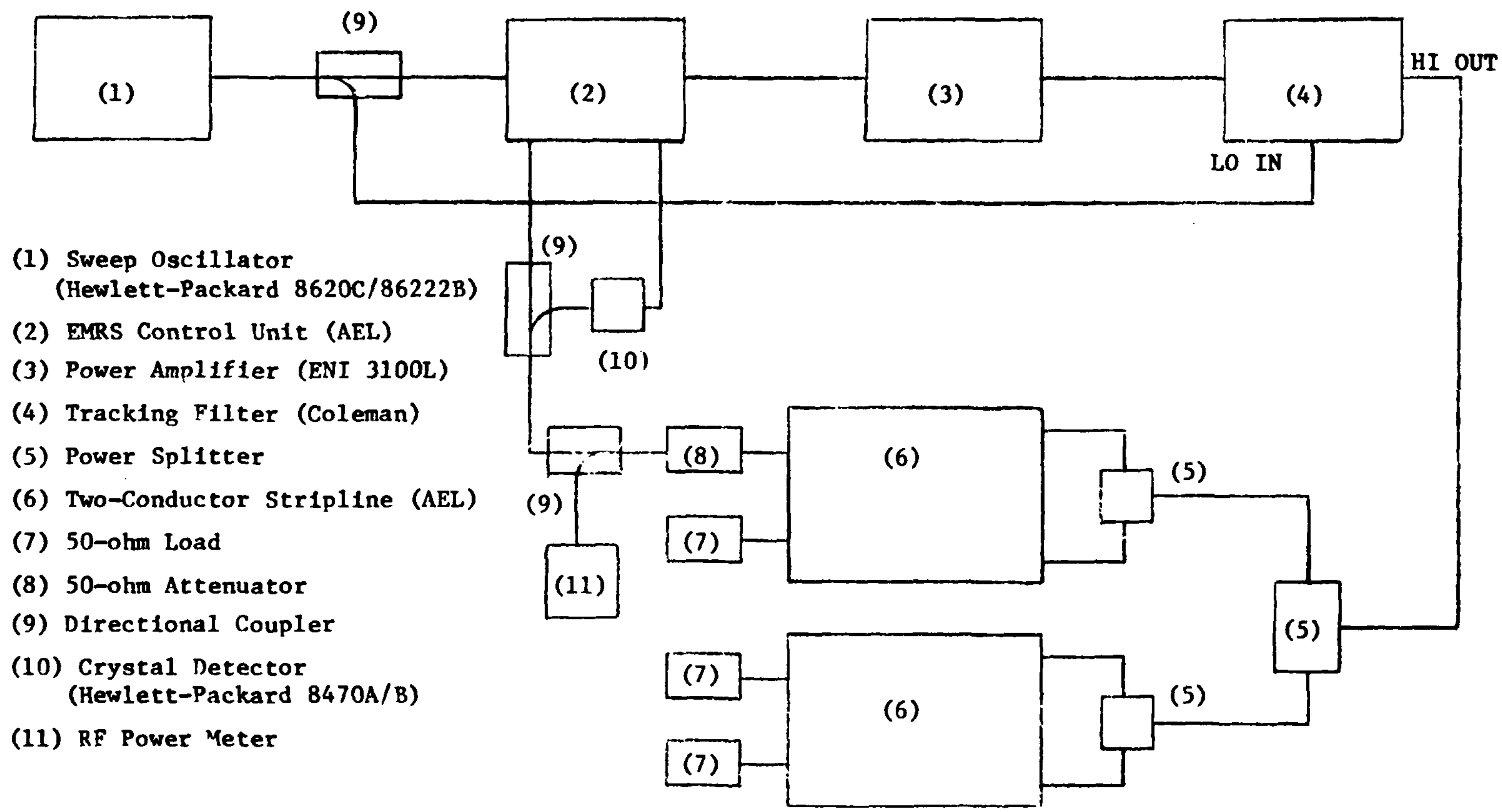
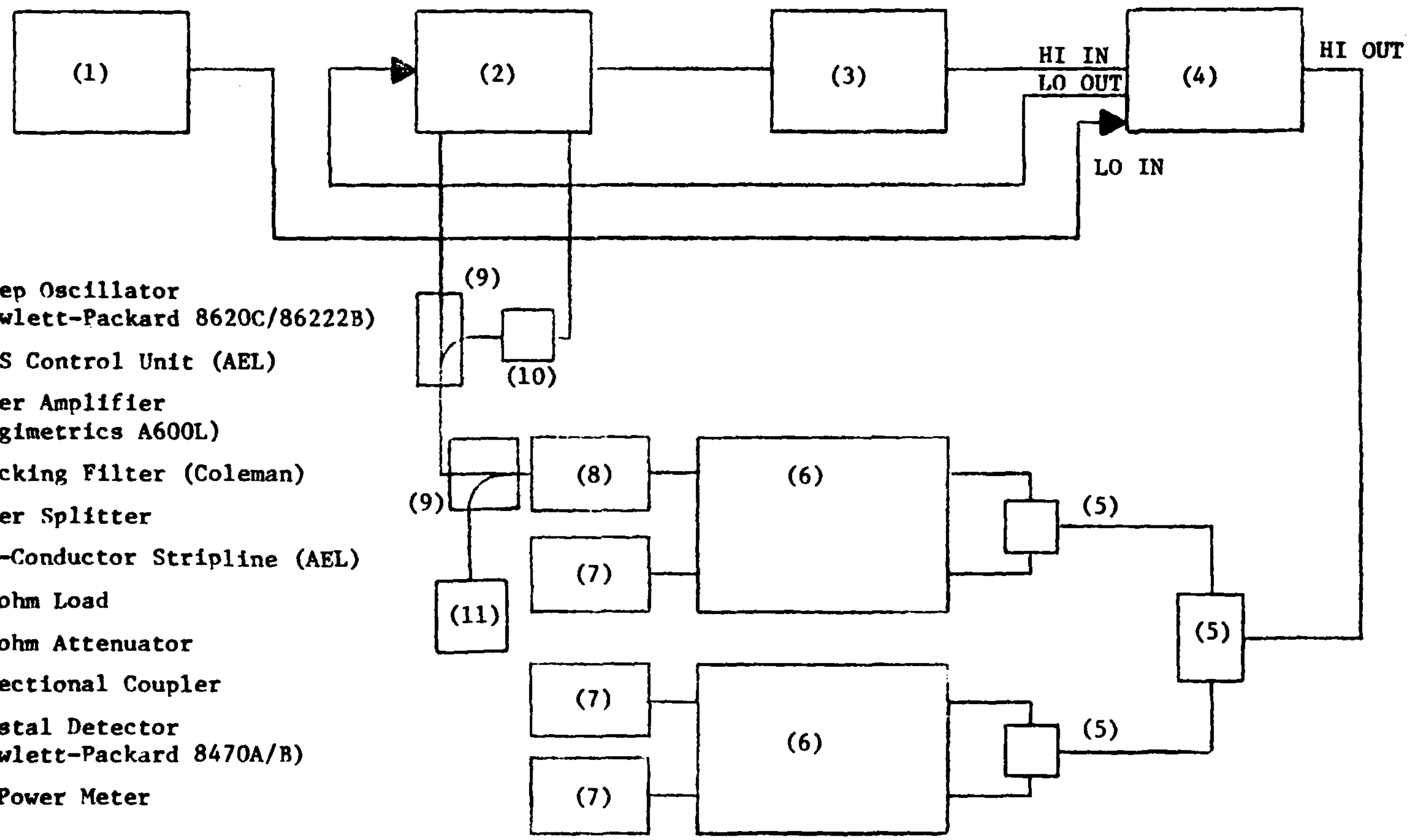
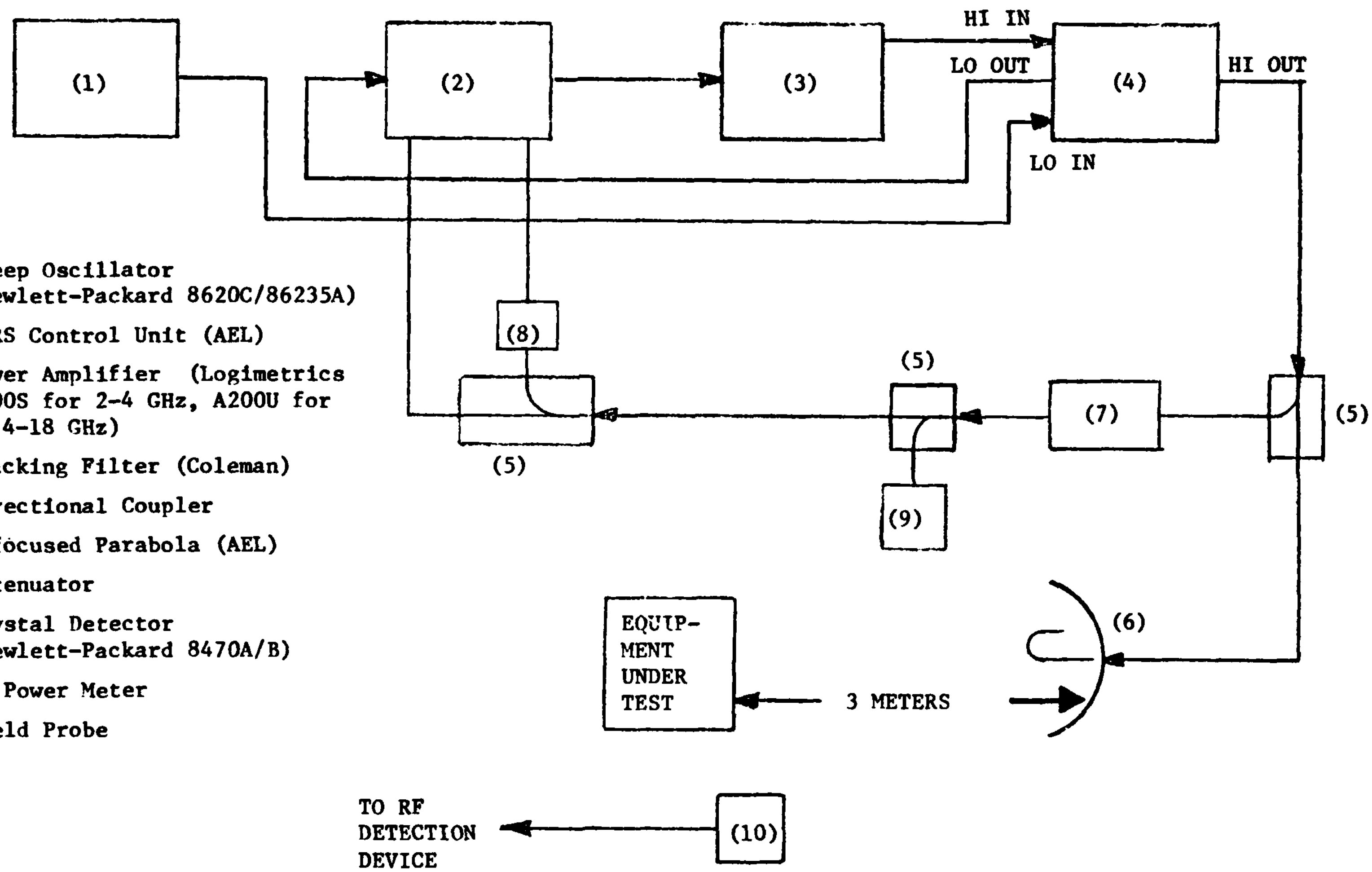


Figure 1. 30 to 60 MHz EMRS System Block Diagram



(1) Sweep Oscillator (Hewlett-Packard 8620C/86222B)
(2) EMRS Control Unit (AEL)
(3) Power Amplifier (Logimetrics A600L)
(4) Tracking Filter (Coleman)
(5) Power Splitter
(6) Two-Conductor Stripline (AEL)
(7) 50-ohm Load
(8) 50-ohm Attenuator
(9) Directional Coupler
(10) Crystal Detector (Hewlett-Packard 8470A/B)
(11) RF Power Meter

Figure 2. 1.0 to 2.1 GHz EMRS System Block Diagram



(1) Sweep Oscillator (Hewlett-Packard 8620C/86235A)

(2) EMRS Control Unit (AEL)

(3) Power Amplifier (Logimetrics A600S for 2-4 GHz, A200U for 12.4-18 GHz)

(4) Tracking Filter (Coleman)

(5) Directional Coupler

(6) Refocused Parabola (AEL)

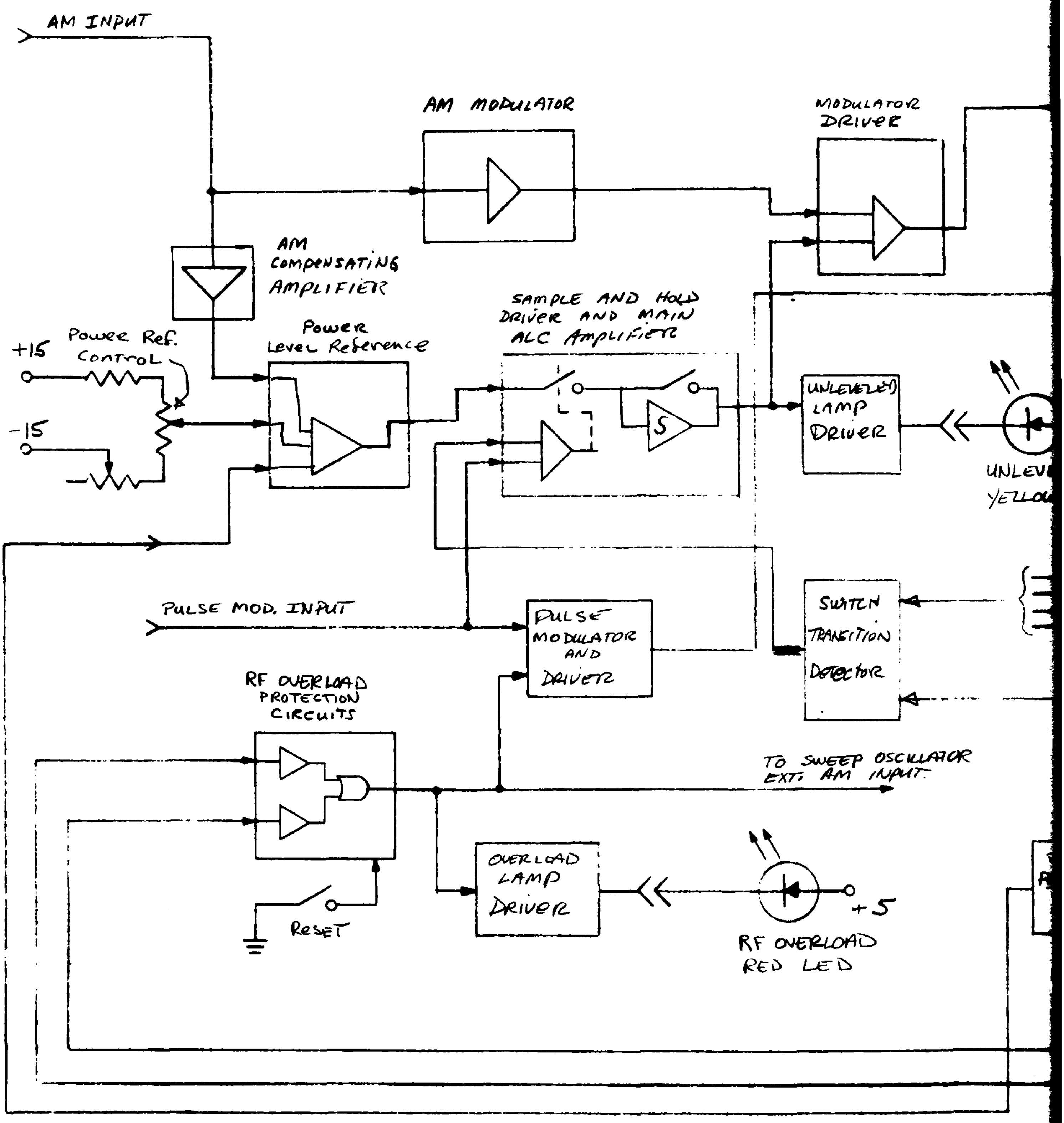
(7) Attenuator

(8) Crystal Detector (Hewlett-Packard 8470A/B)

(9) RF Power Meter

(10) Field Probe

Figure 3. 2.1 to 4.0 GHz and 12.4 to 18 GHz EMRS System Block Diagram



AM INPUT
AM MODULATOR
MODULATOR DRIVER
AM COMPENSATING AMPLIFIER
SAMPLE AND HOLD DRIVER AND MAIN ALC AMPLIFIER
Power Level Reference
Power Ref. Control
+15
-15
S
UNLEVELED LAMP DRIVER
PULSE MOD. INPUT
PULSE MODULATOR AND DRIVER
SWITCH TRANSITION Detector
RF OVERLOAD PROTECTION CIRCUITS
TO SWEEP OSCILLATOR EXT. AM INPUT
OVERLOAD LAMP DRIVER
RESET
+5
RF OVERLOAD RED LED

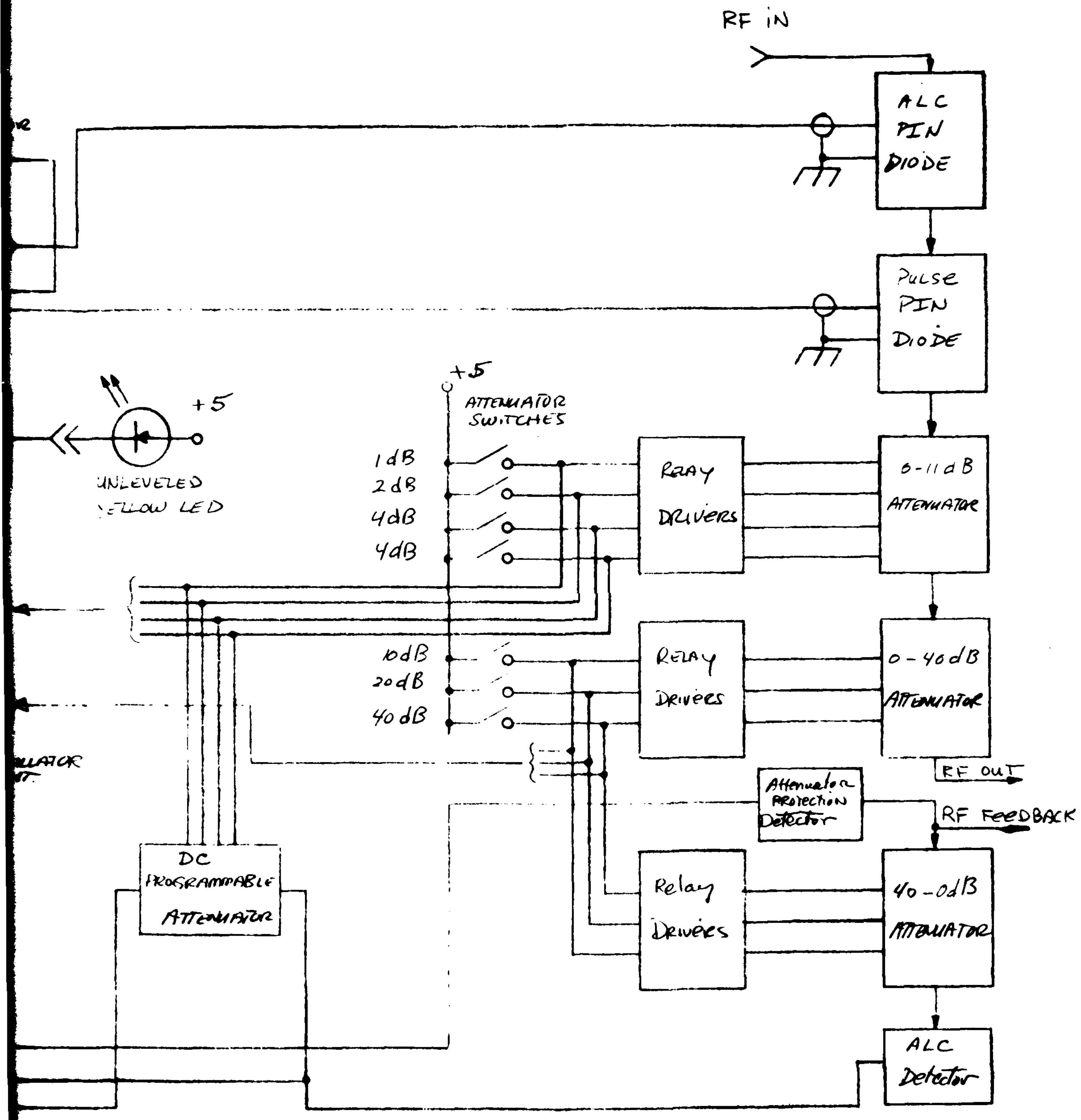


figure 4 EMRS CONTROL ASSEMBLY
BLOCK DIAGRAM

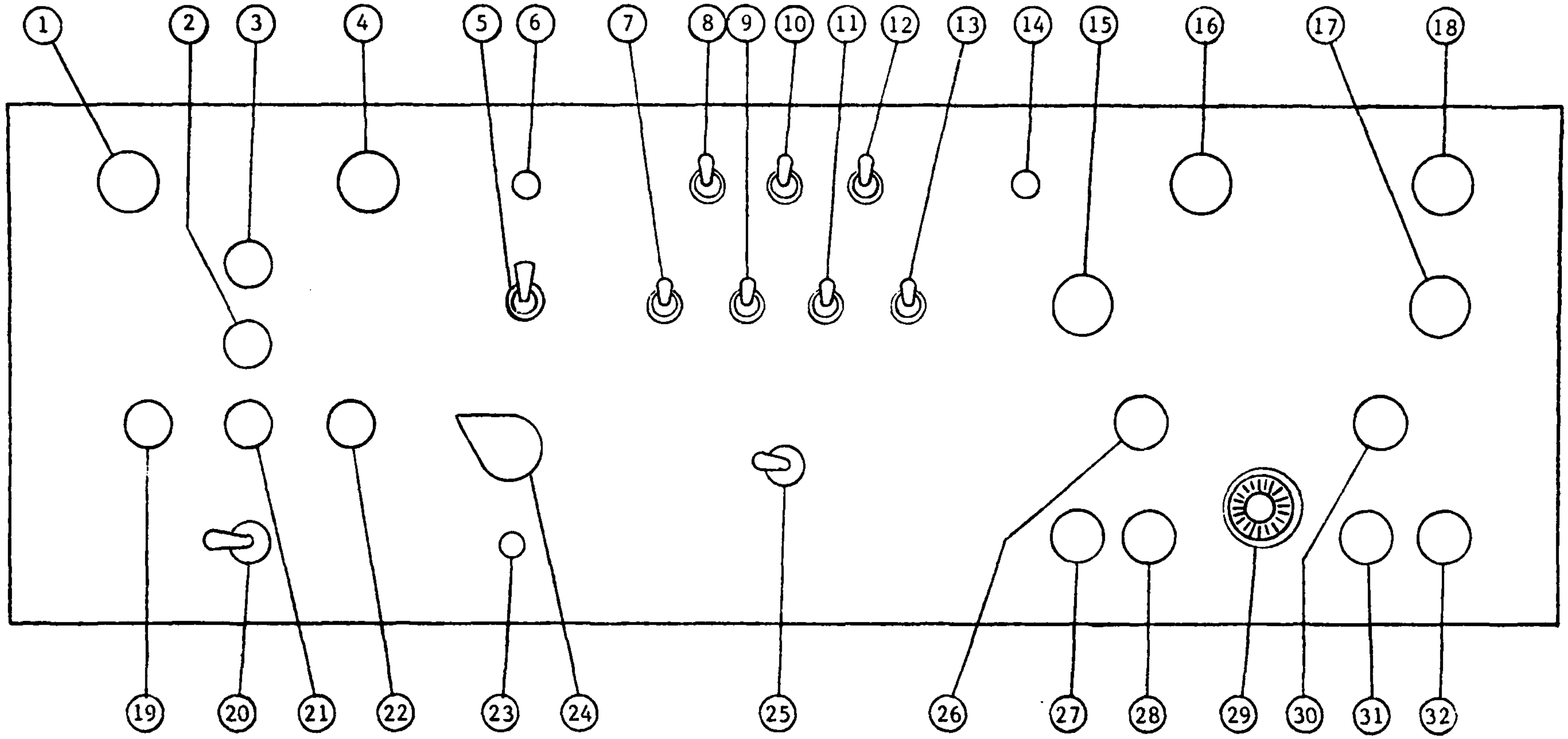


Figure 5. EMRS Control Panel.

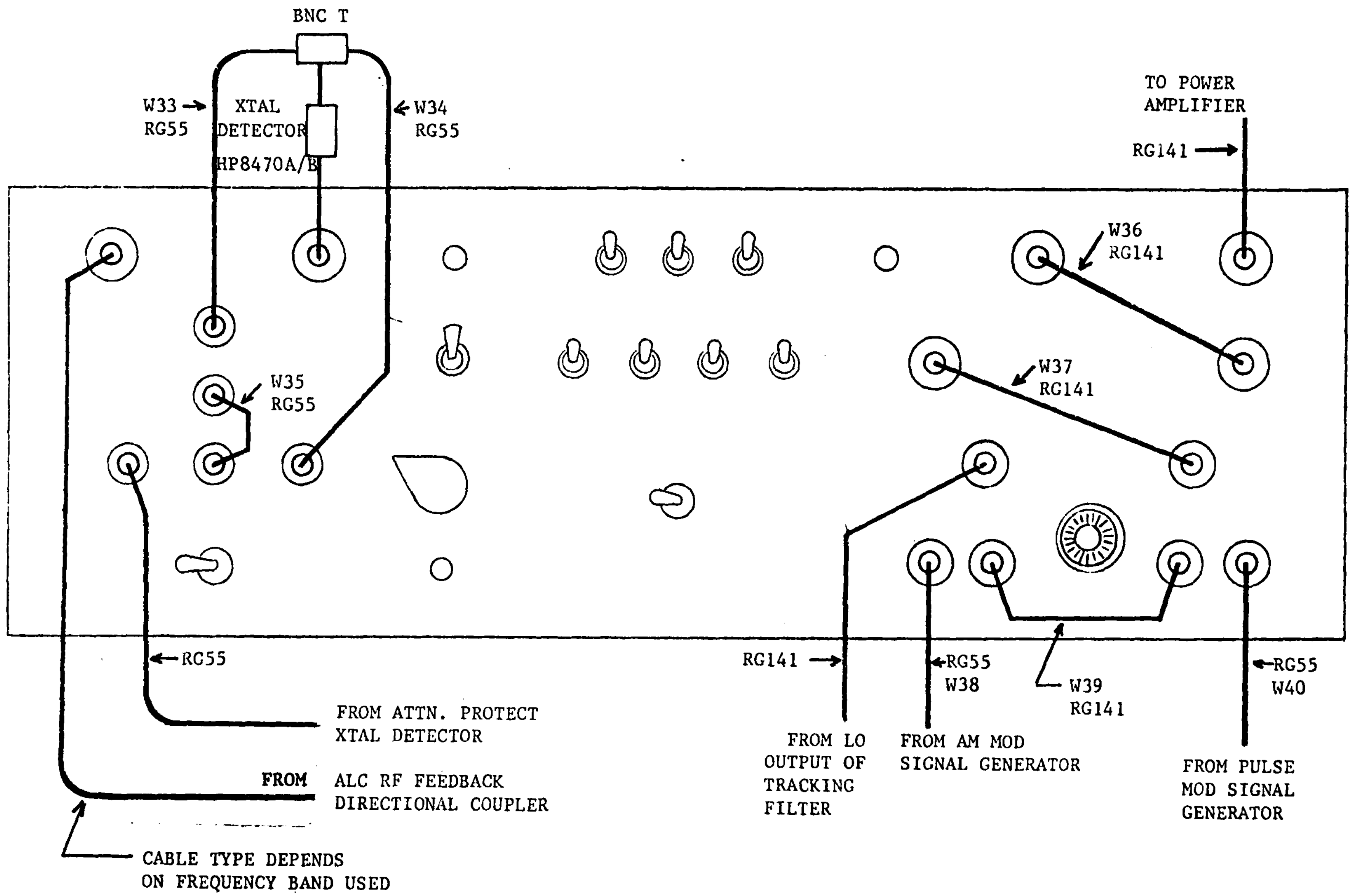


Figure 6. Control Panel RF Interconnections

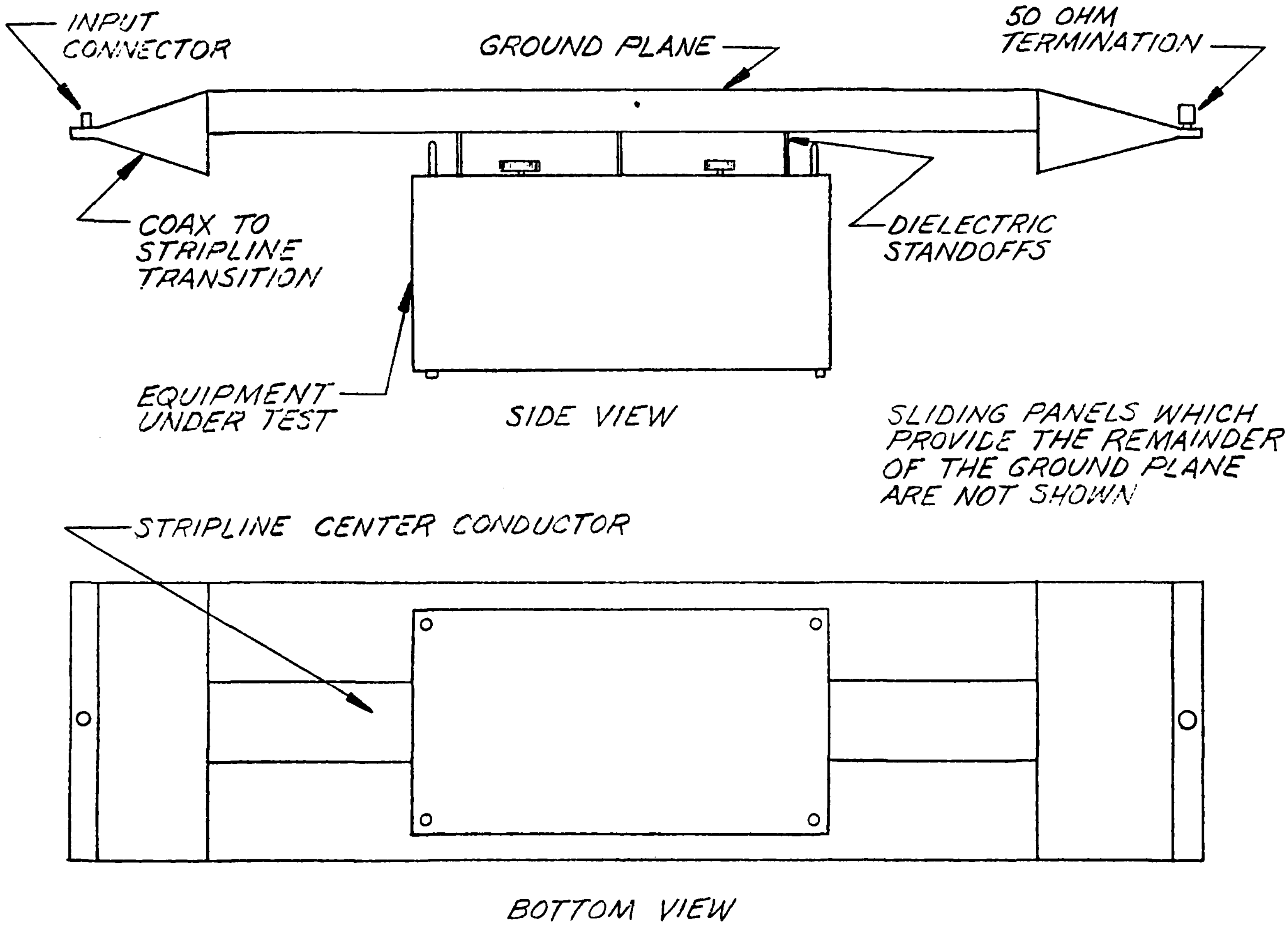


FIGURE 7 STRIPLINE SHOWN LOCATED OVER EQUIPMENT TO BE TESTED

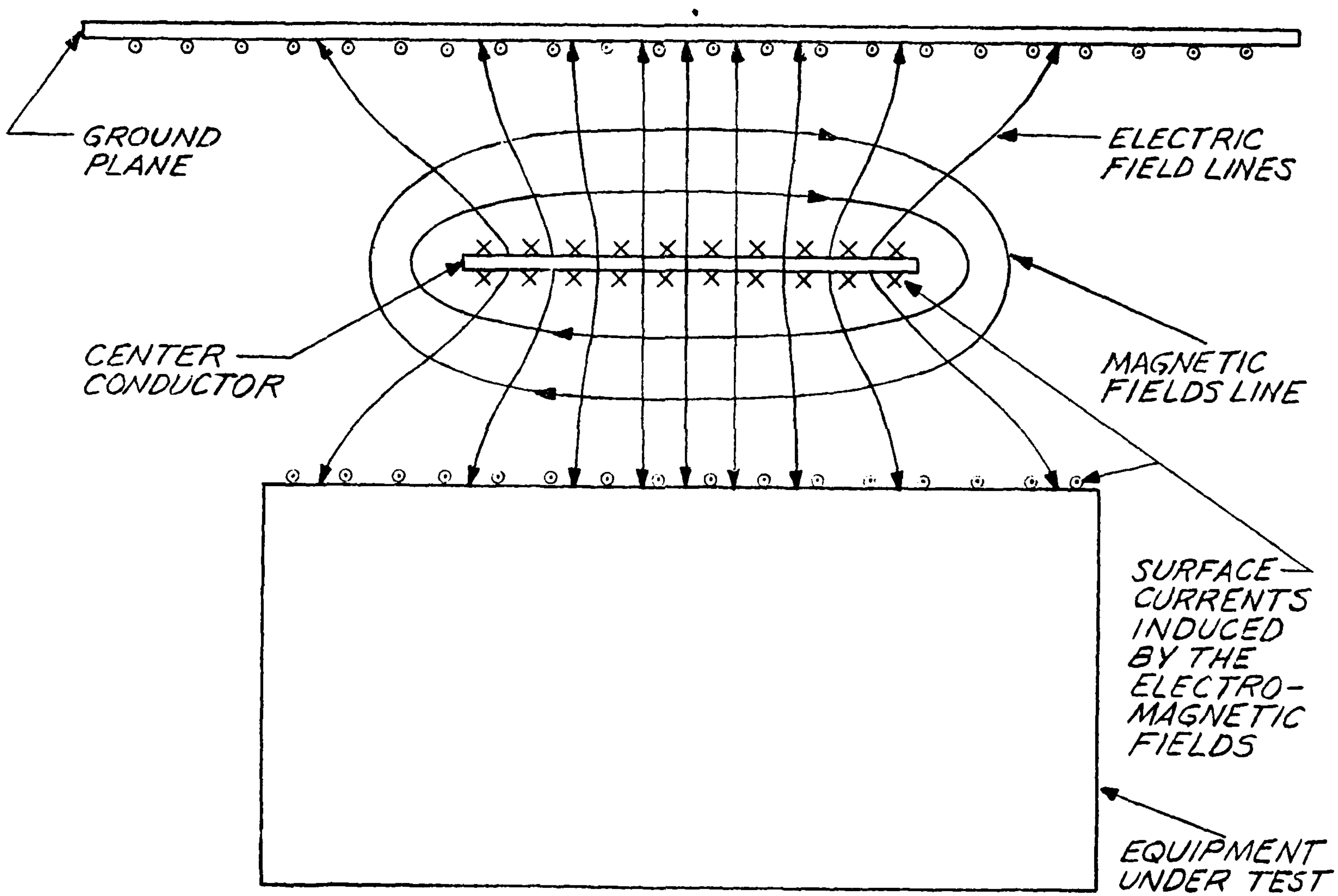


FIGURE 8 ELECTRIC AND MAGNETIC FIELDS AND INDUCED SURFACE CURRENTS IN THE STRIPLINE SYSTEM

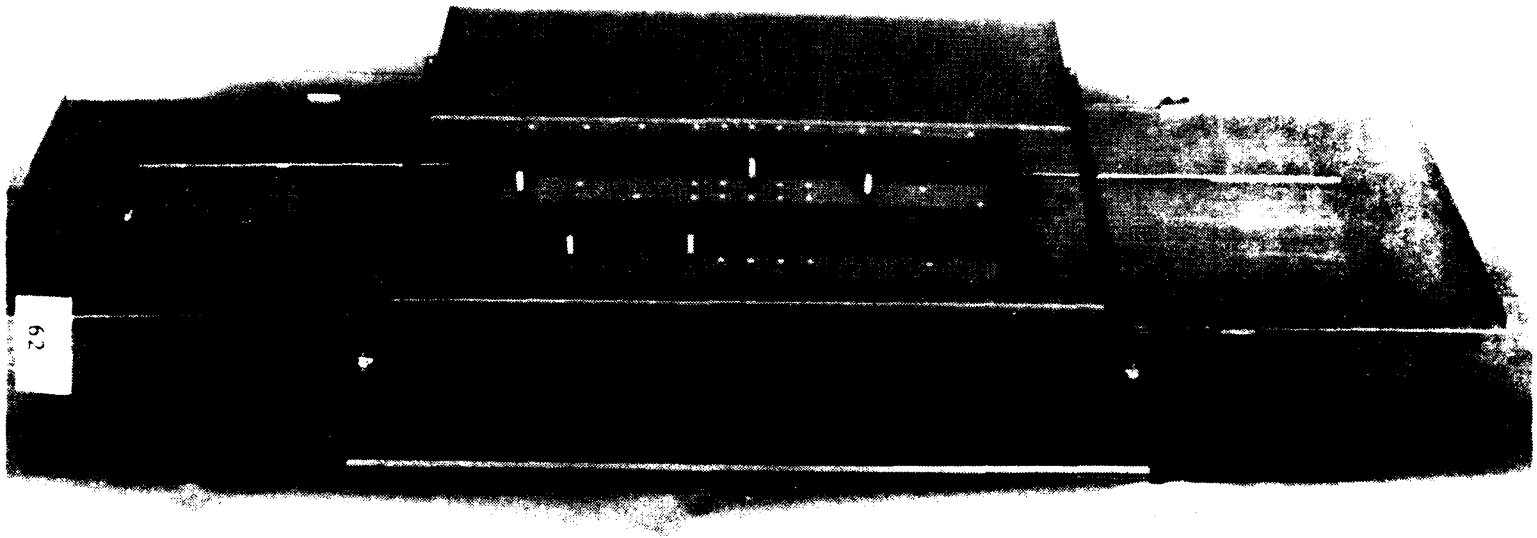


Figure 9. Two-Conductor Stripline Field Generating System

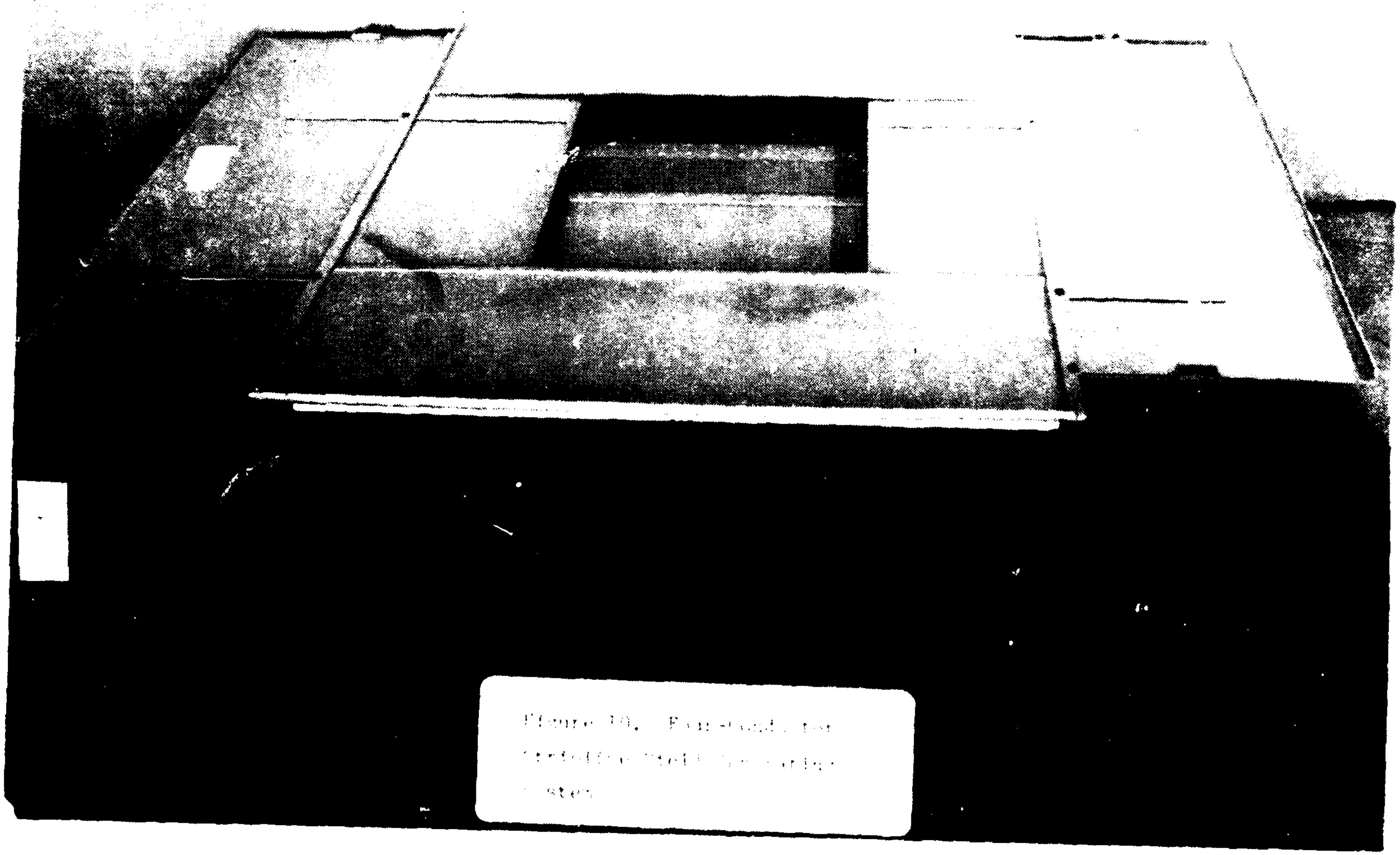


Figure 10.

Figure 11. Experimentally Determined Equivalence Between Radiated and Stripline Measurement Techniques for Susceptibility Testing

Frequency GHz	X
1.0	6.22
1.25	6.58
1.5	5.72
1.75	6.10
2.0	7.30

$\bar{X} = 6.38$

$\sqrt{X} = 2.63$

$$X = \frac{\text{Power Received from Radiated Field}}{\text{Power Received from Stripline Field}}$$

Receiving aperture is a 6 x 0.3 inch slot in a 19 x 15 x 6 inch conductive box.

If desired field intensity is between

100 - 1000 V/m	A = 0
10 - 100	A = -2
1 - 10	A = -4
.1 - 1	A - -6
.01 - .1	A = -8
.001 - .01	A = -10

Power required per line to generate a specified field strength (nominal). The The peak field intensity is 3 db higher than nominal.

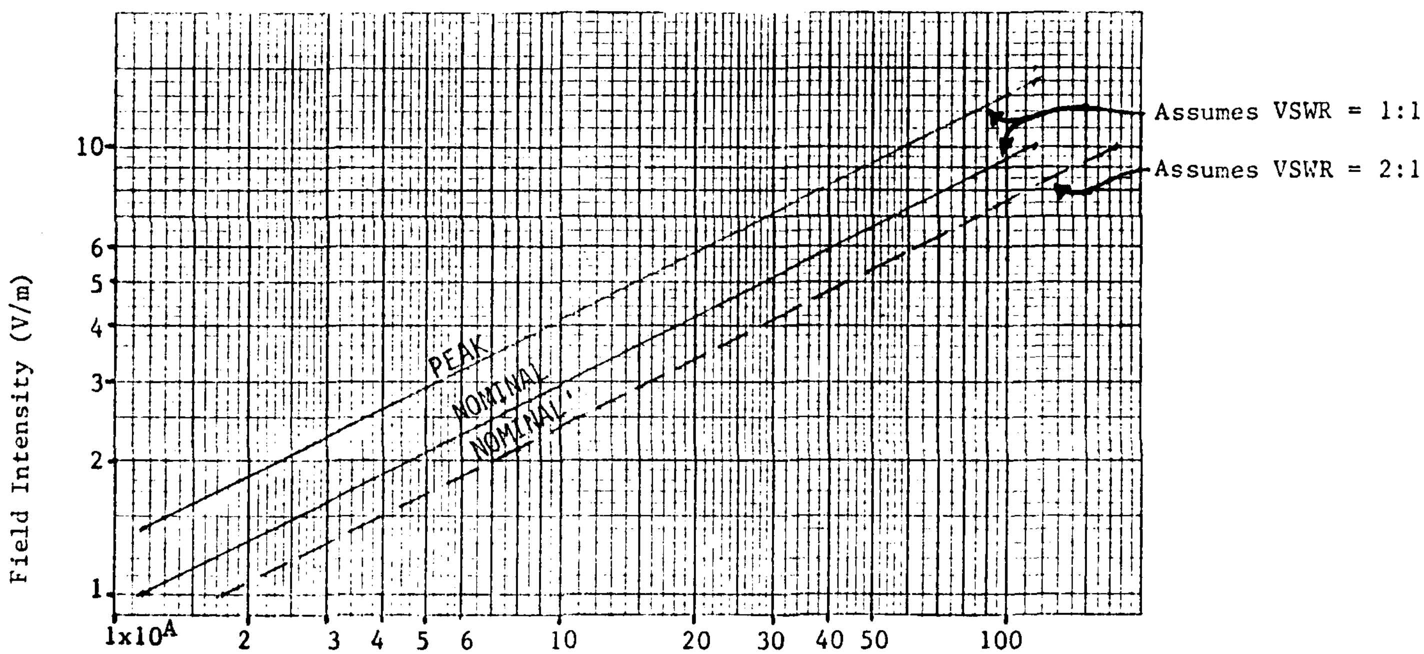
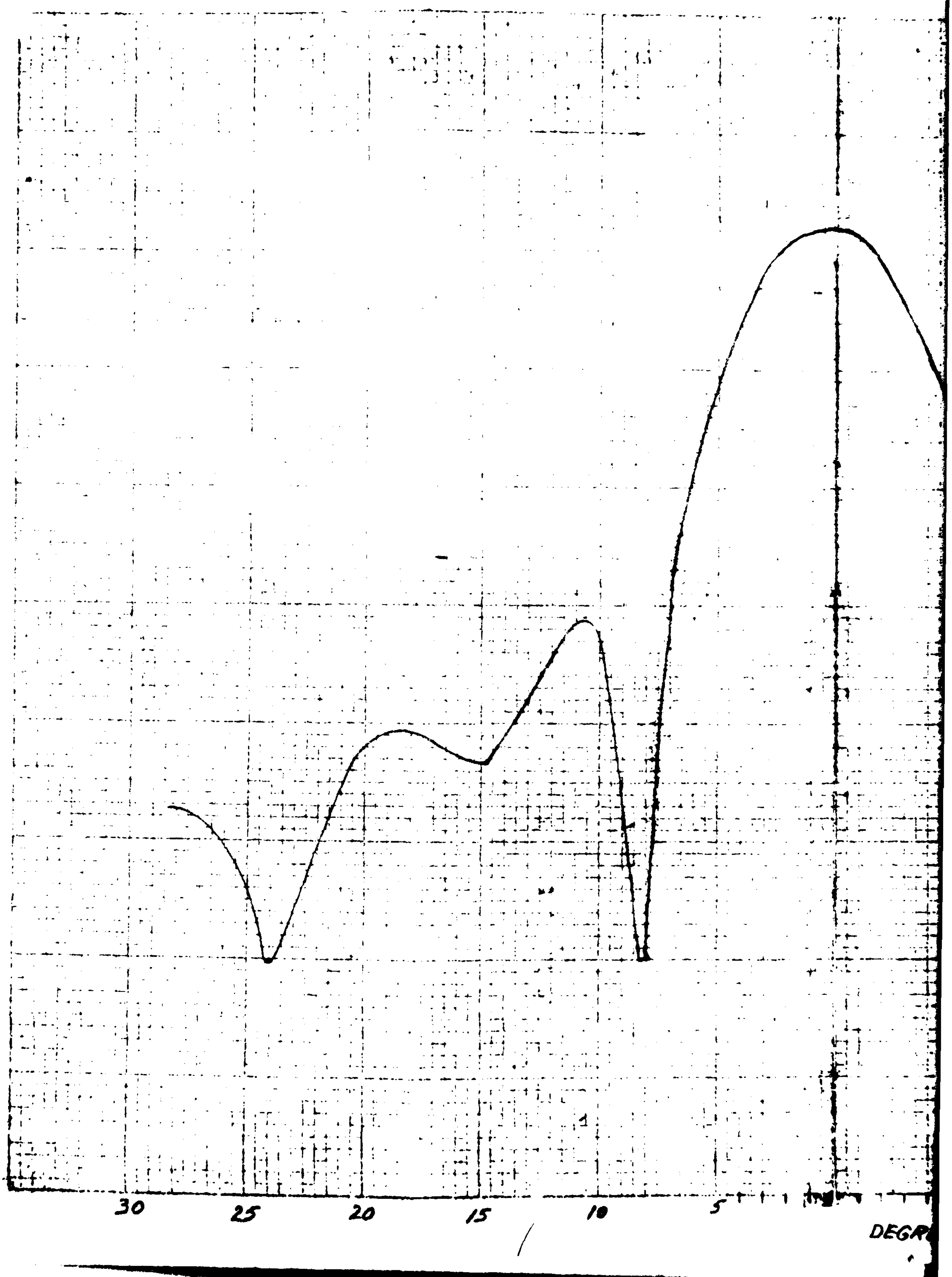


Figure 12. Field intensity vs. power input for the stripline.



30
25
20
15
10
5
DEGR

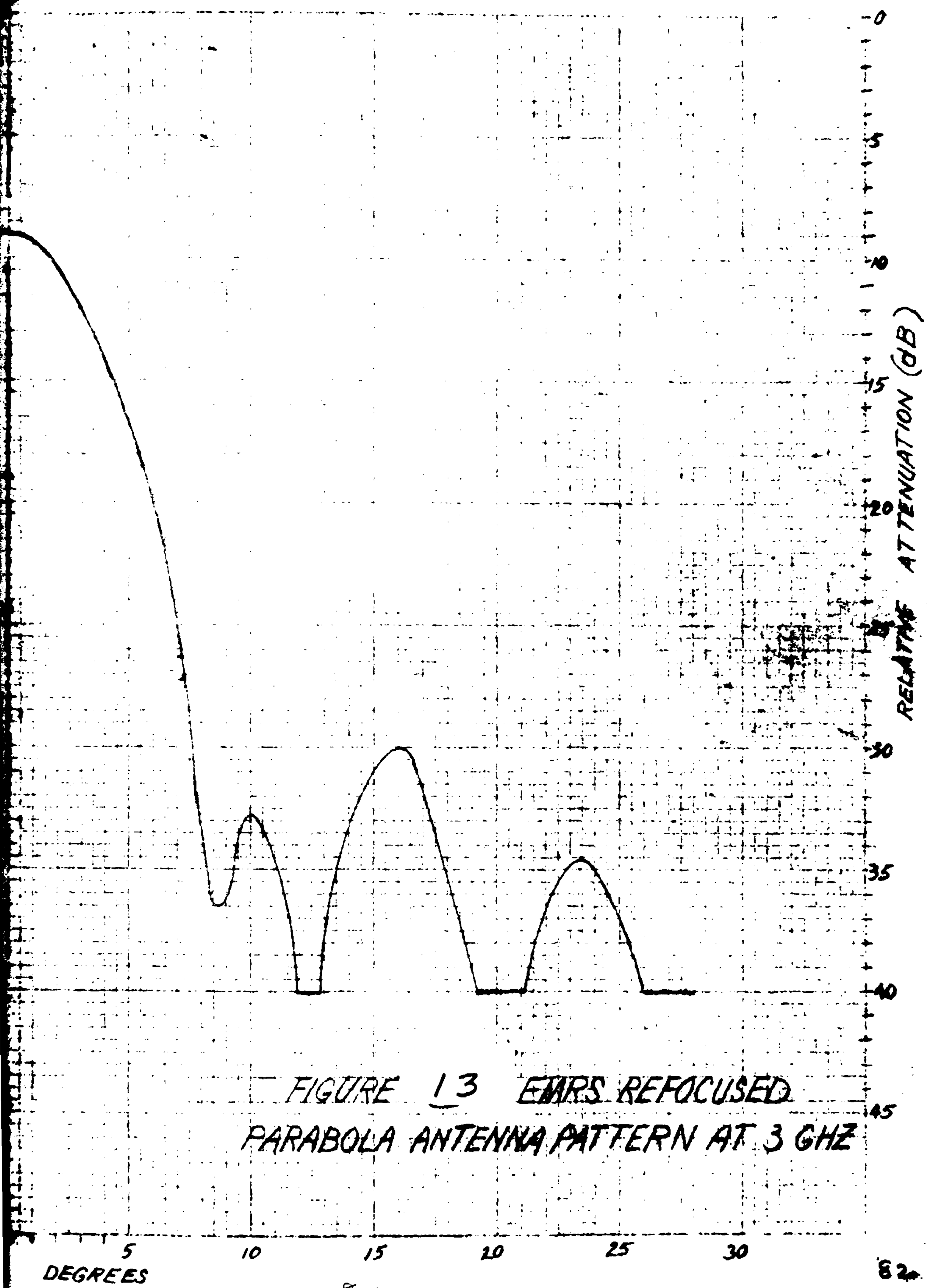


FIGURE 13 EMRS REFOCUSED PARABOLA ANTENNA PATTERN AT 3 GHZ

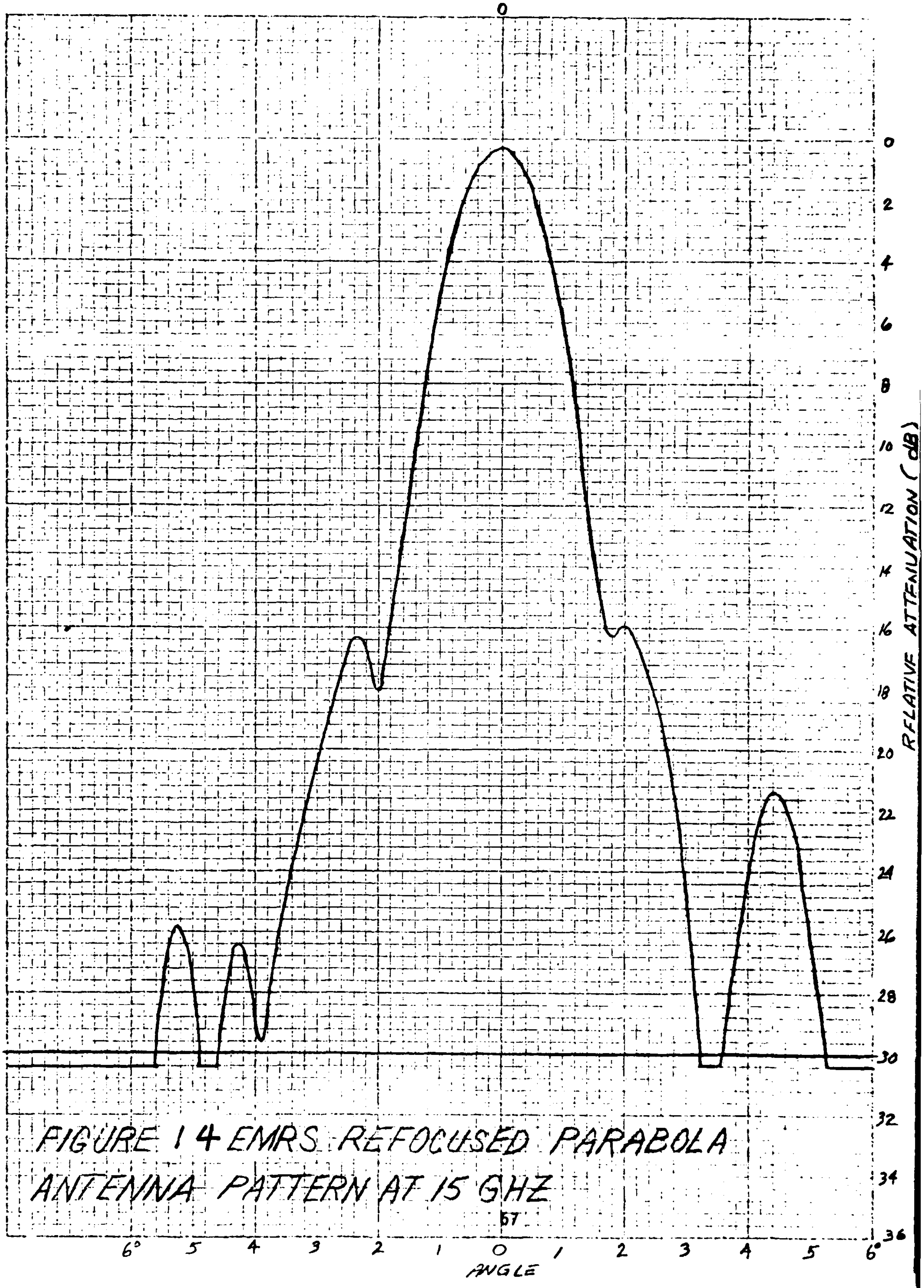


FIGURE 14 EMRS REFOCUSED PARABOLA ANTENNA PATTERN AT 15 GHZ

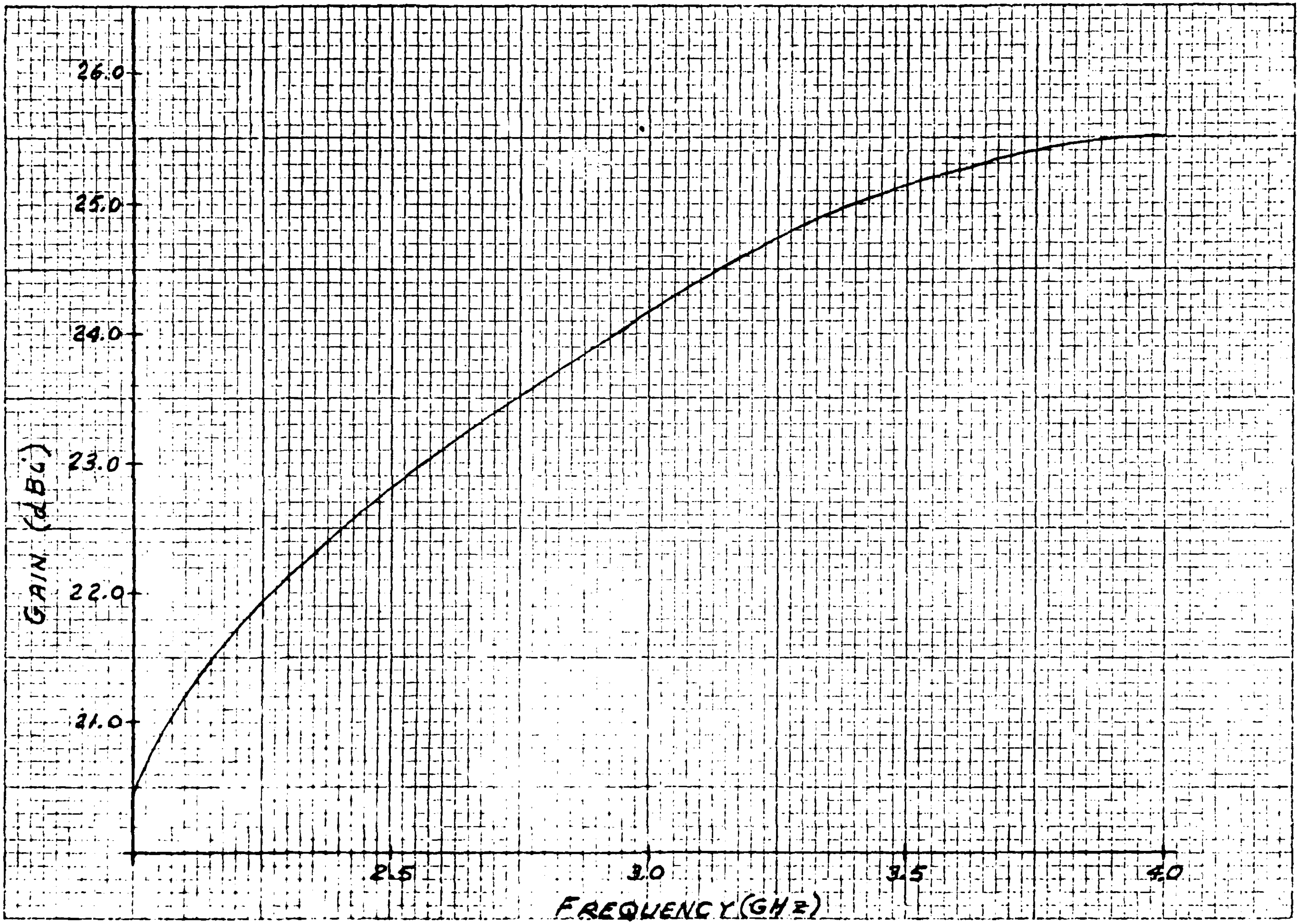


FIGURE 15 GAIN OF 2 TO 4 GHZ REFOCUSED PARABOLA

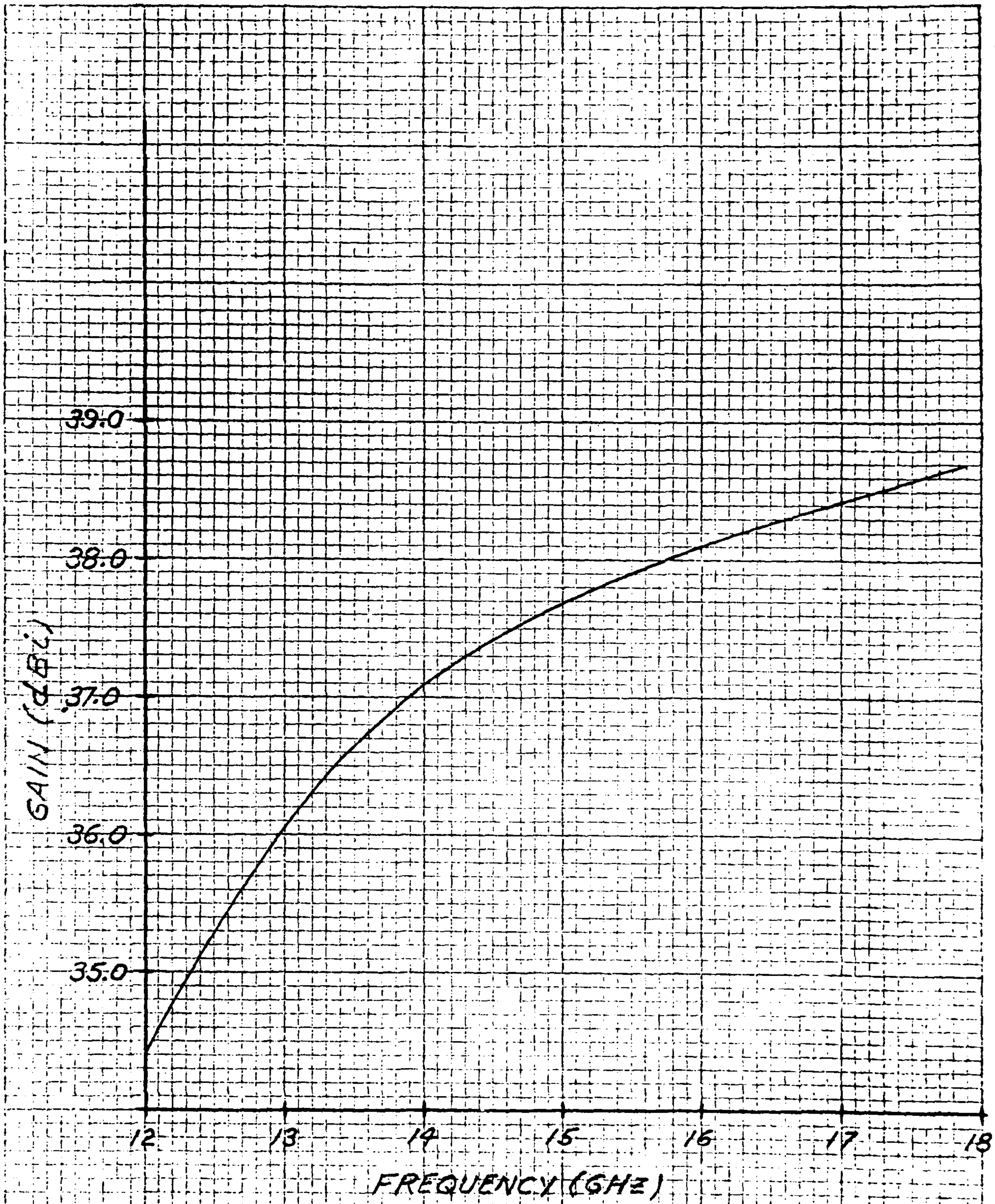
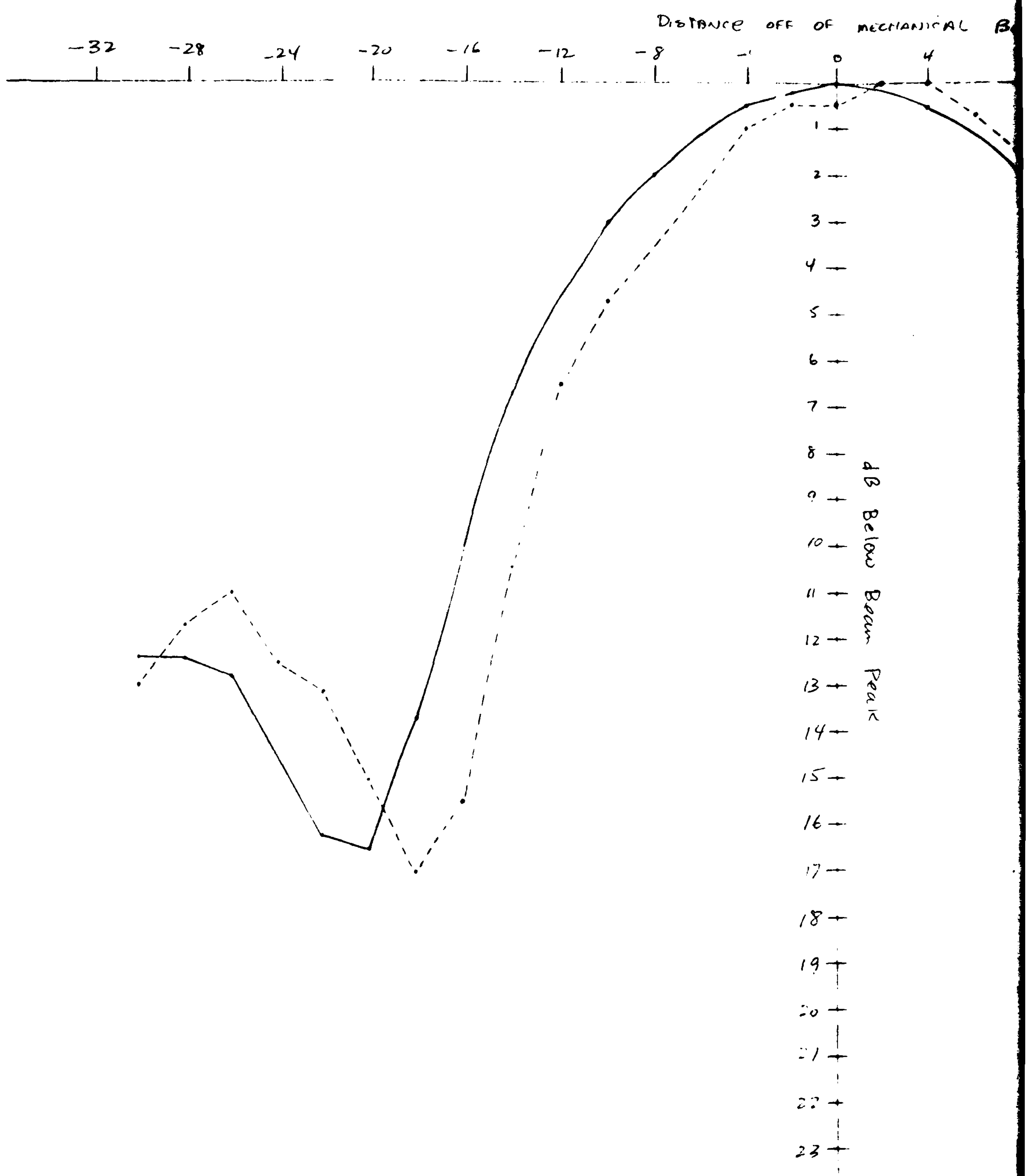


FIGURE 16 GAIN OF 12 TO 18 GHZ REFOCUSED PARABOLA


DISTANCE OFF OF MECHANICAL B
-32
-28
-24
-20
-16
-12
-8
0
4
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
dB Below Beam Peak

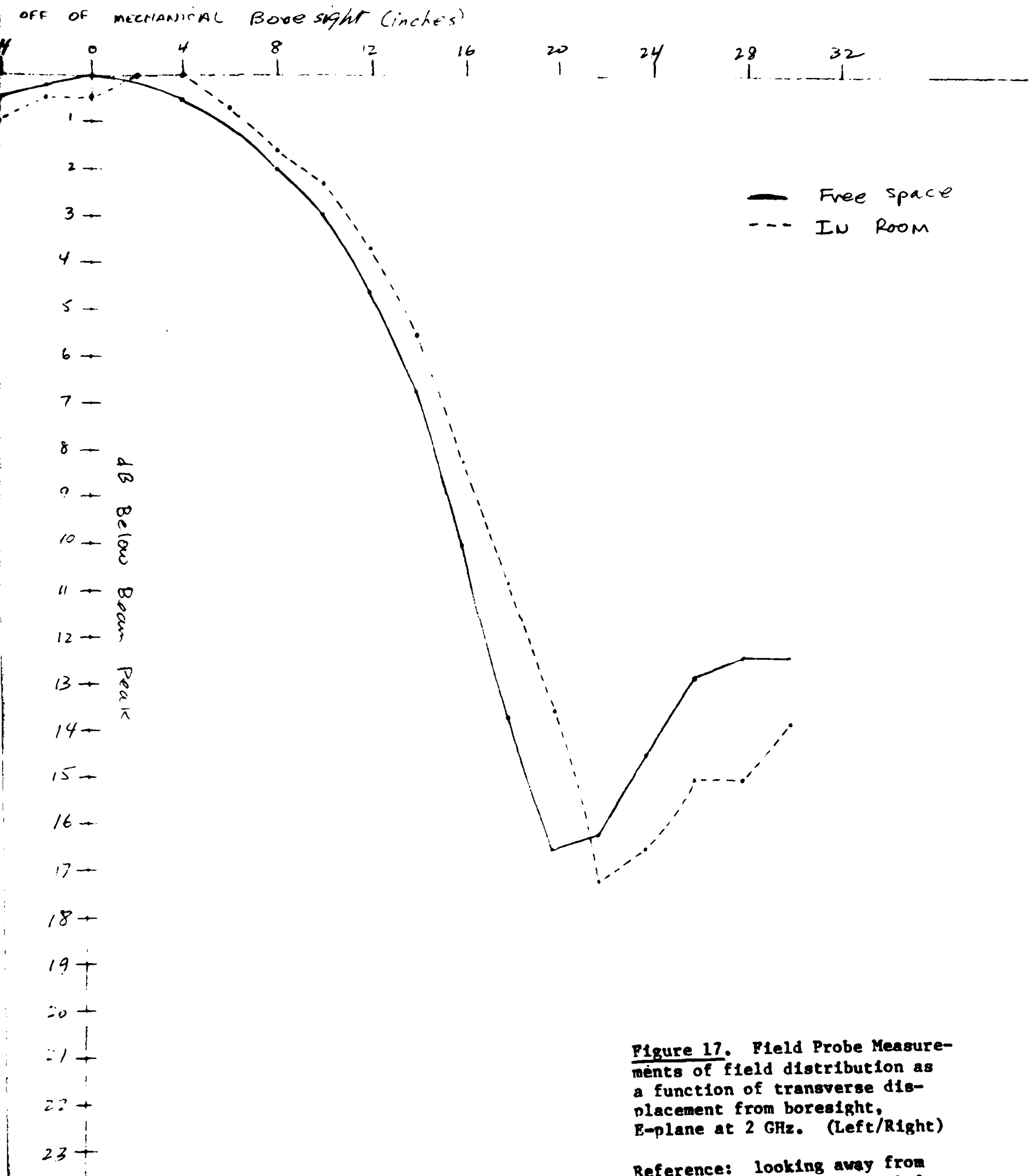
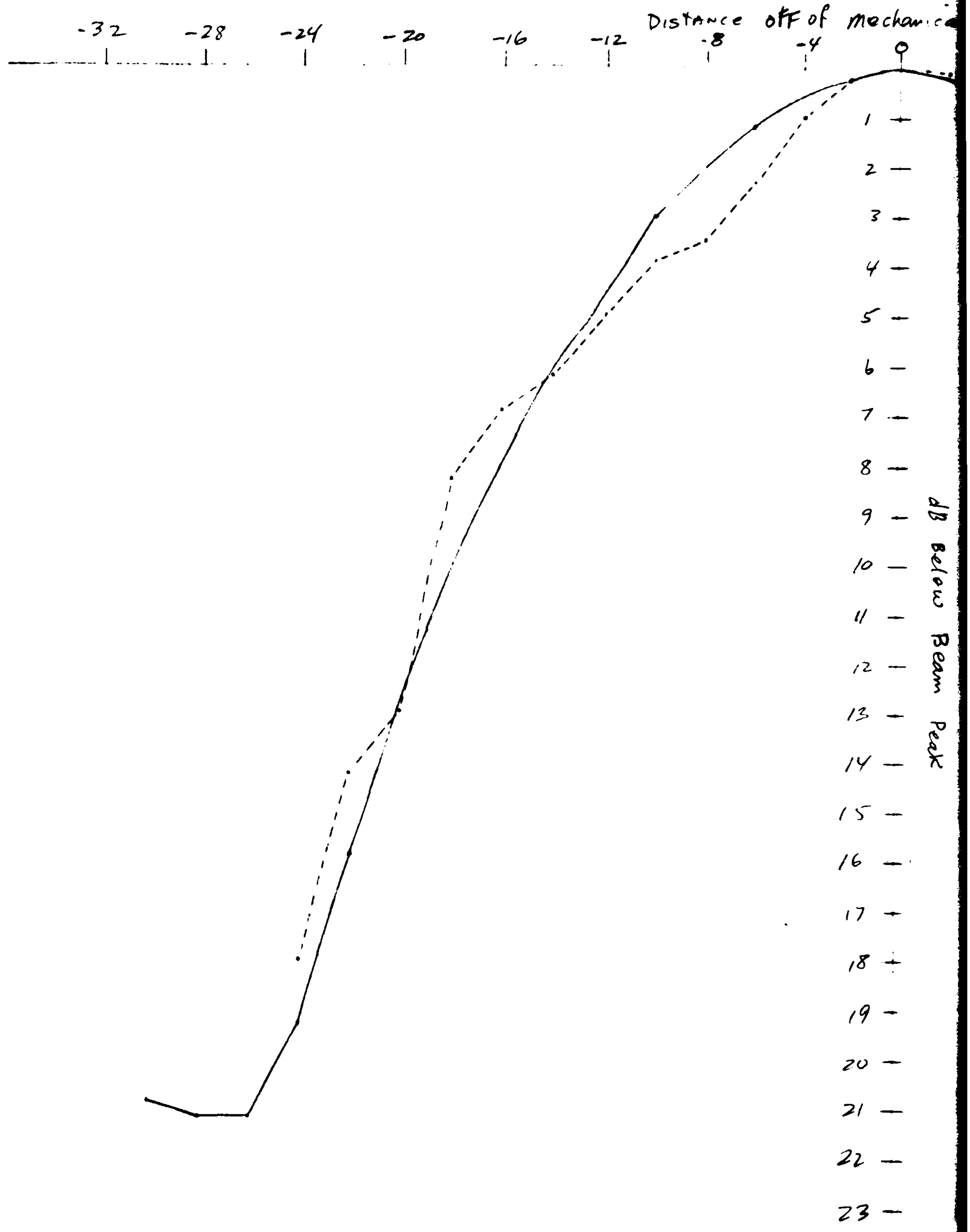


Figure 17. Field Probe Measurements of field distribution as a function of transverse displacement from boresight, E-plane at 2 GHz. (Left/Right)

Reference: looking away from refocused parabola

2



Distance off of mechanic
-32
-28
-24
-20
-16
-12
-8
-4
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
dB Below Beam Peak

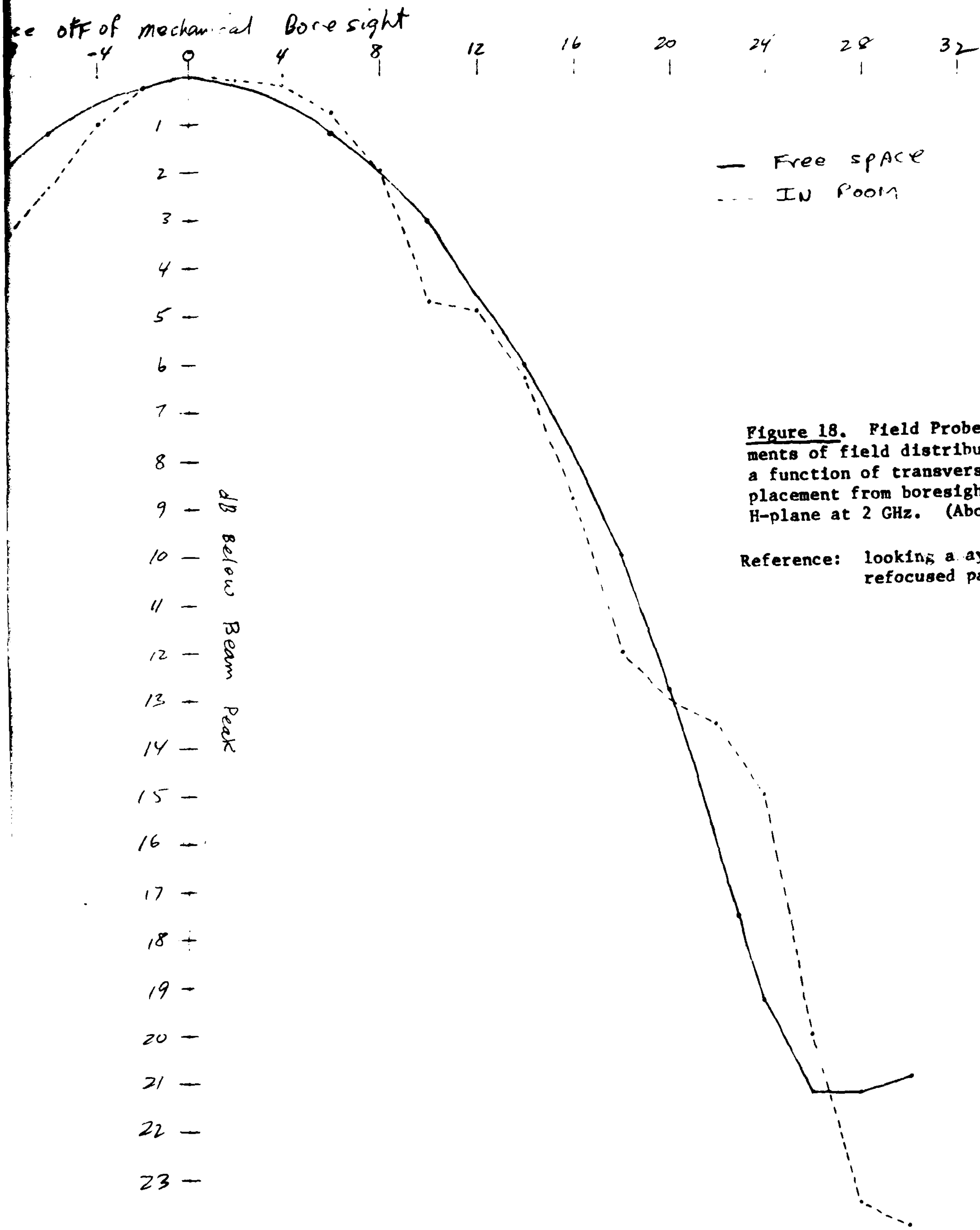


Figure 18. Field Probe Measurements of field distribution as a function of transverse displacement from boresight, H-plane at 2 GHz. (Above/Below)

Reference: looking a ay from refocused parabola

If desired field intensity is between

100 - 1000 V/m	A = 1	
10 - 100	A = +1	
1 - 10	A = -3	
.1 - 1	A = -5	
.01 - .1	A = -7	
.001 - .01	A = -9	

Power required to generate a field intensity with 2-4 GHz refocused parabola. Peak field intensity is 3 db higher than that indicated by the curves.

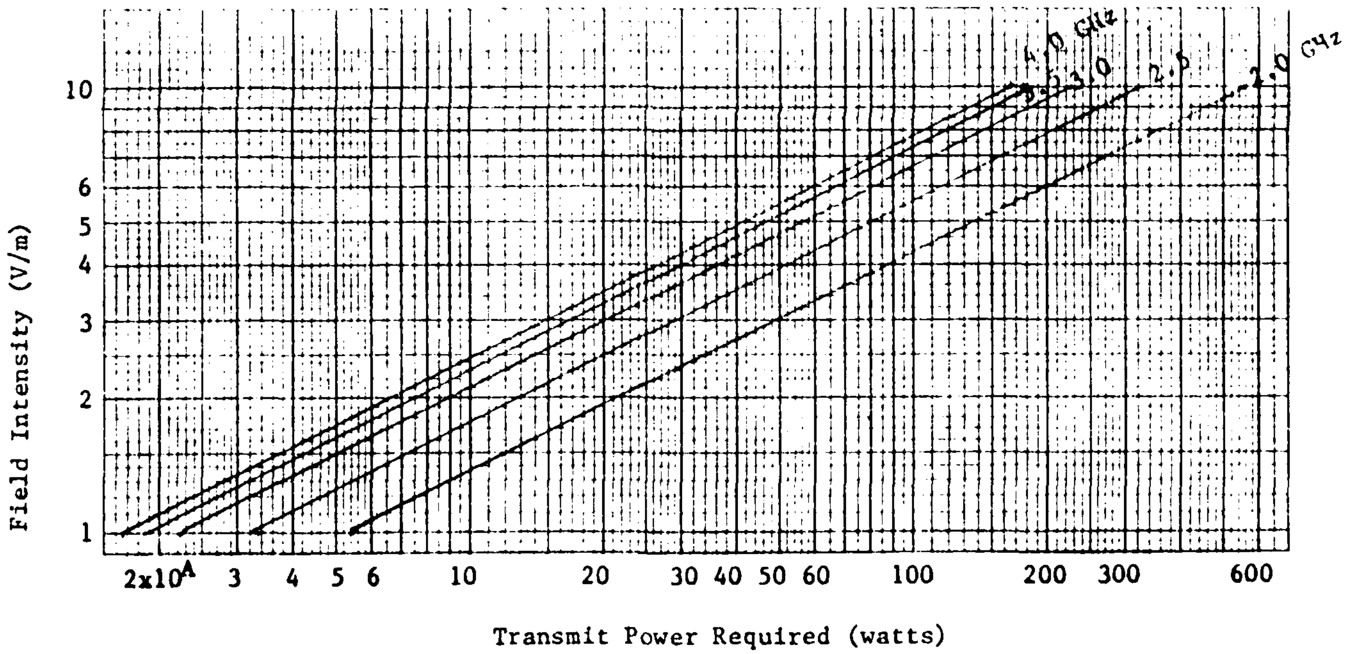


Figure 19. Field intensity vs. power input for the refocused parabola for 2 to 4 GHz.

If desired field intensity is between

100 - 1000 V/m	A = 0
10 - 100	A = -2
1 - 10	A = -4
.1 - 1	A = -6
.01 - .1	A = -8
.001 - .01	A = -10

Power required to generate a given field intensity between 12 and 18 GHz using the refocused parabola. Peak field is 3 db above that shown in the curves.

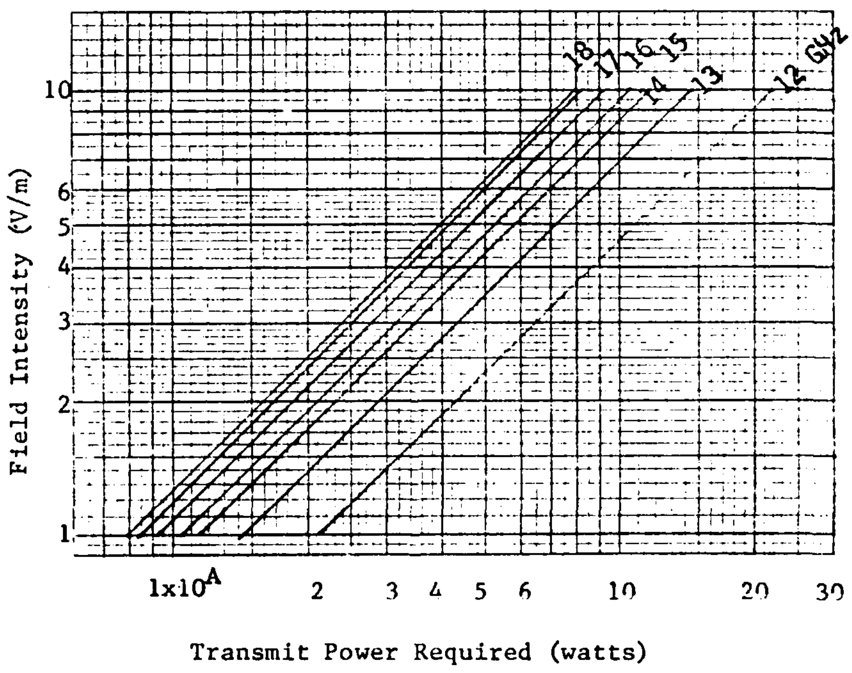


Figure 20. Field intensity vs. power input for the refocused parabola for 12 to 18 GHz

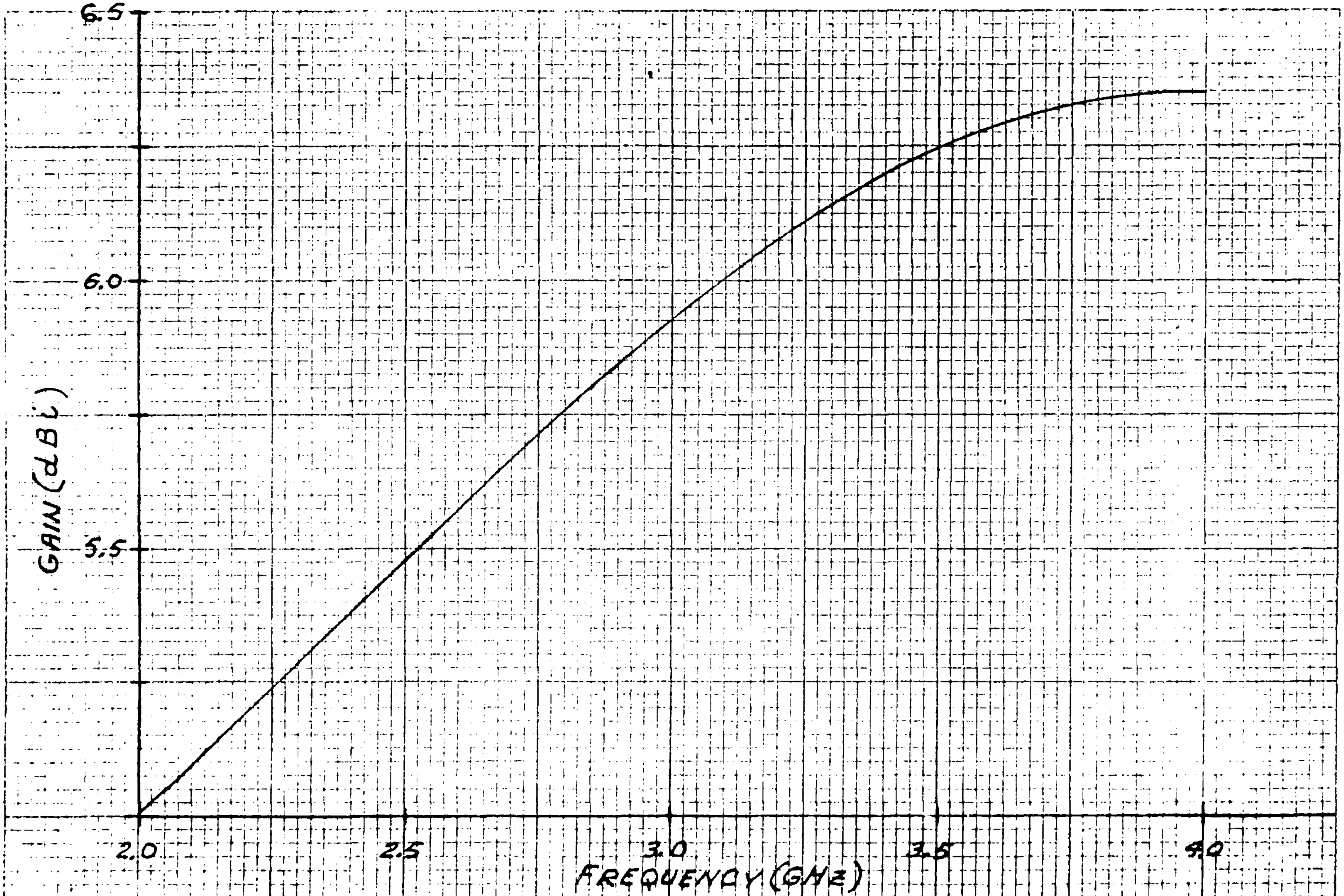


FIGURE 21 GAIN OF 2 TO 4 GHZ FIELD PROBE

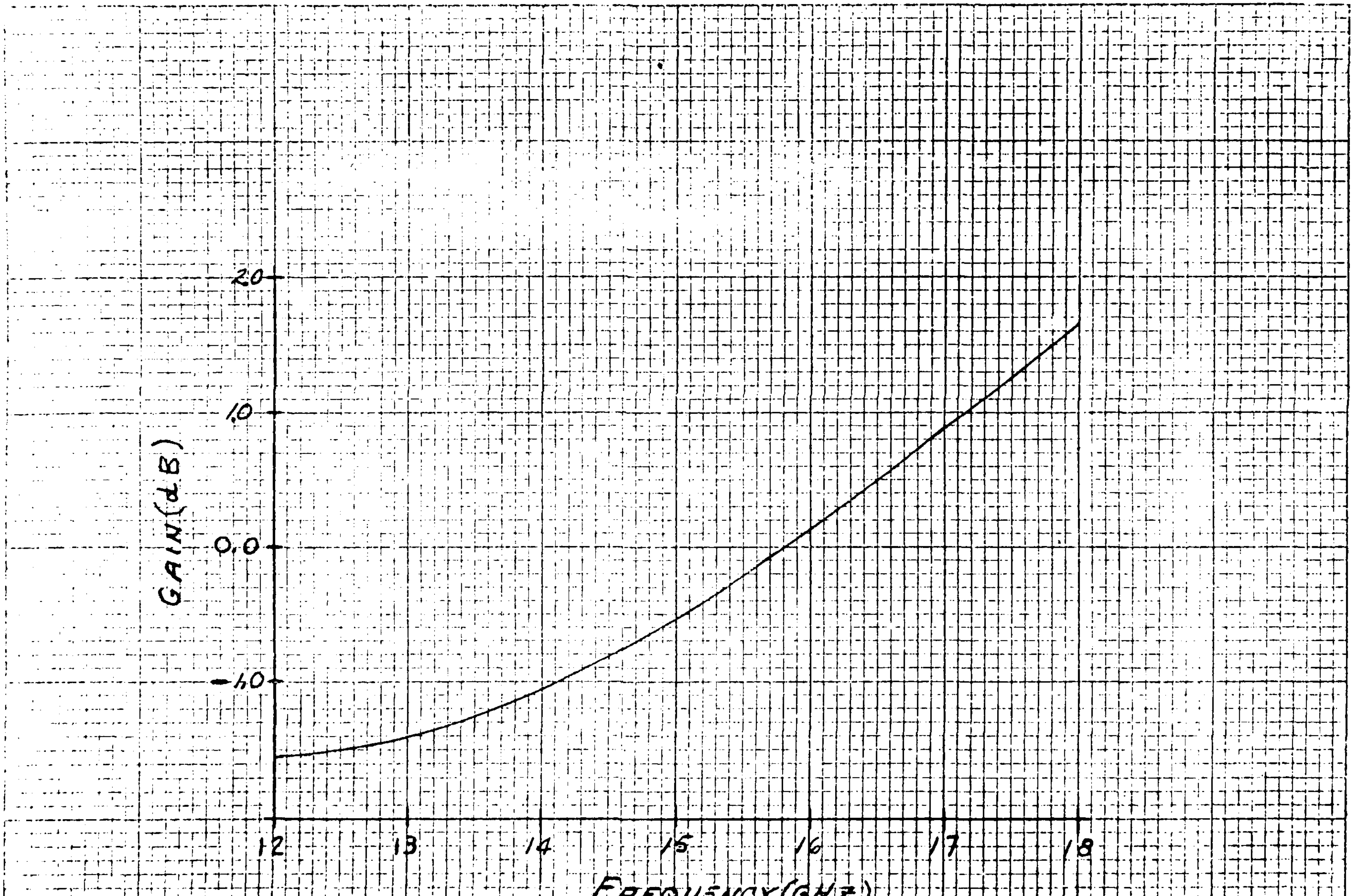


FIGURE 22 GAIN OF 12-18 GHZ FIELD PROBE

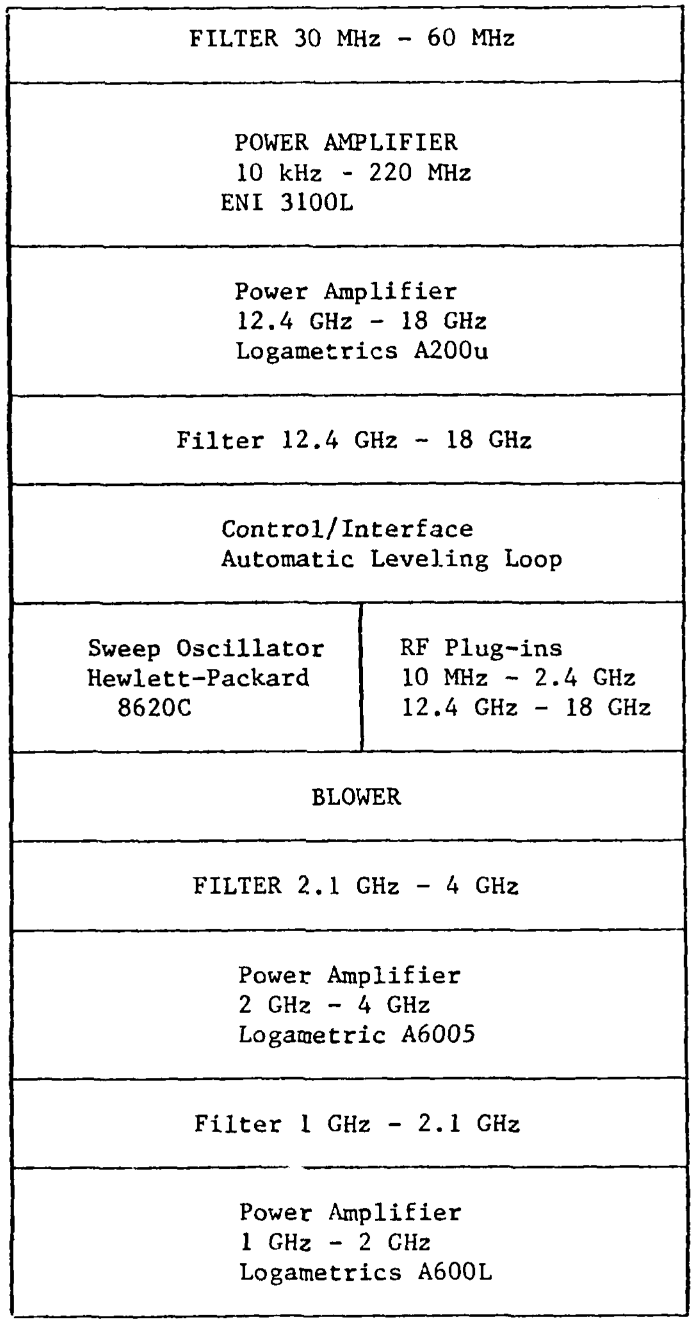


Figure 23. Basic EMRS Equipment Configuration.

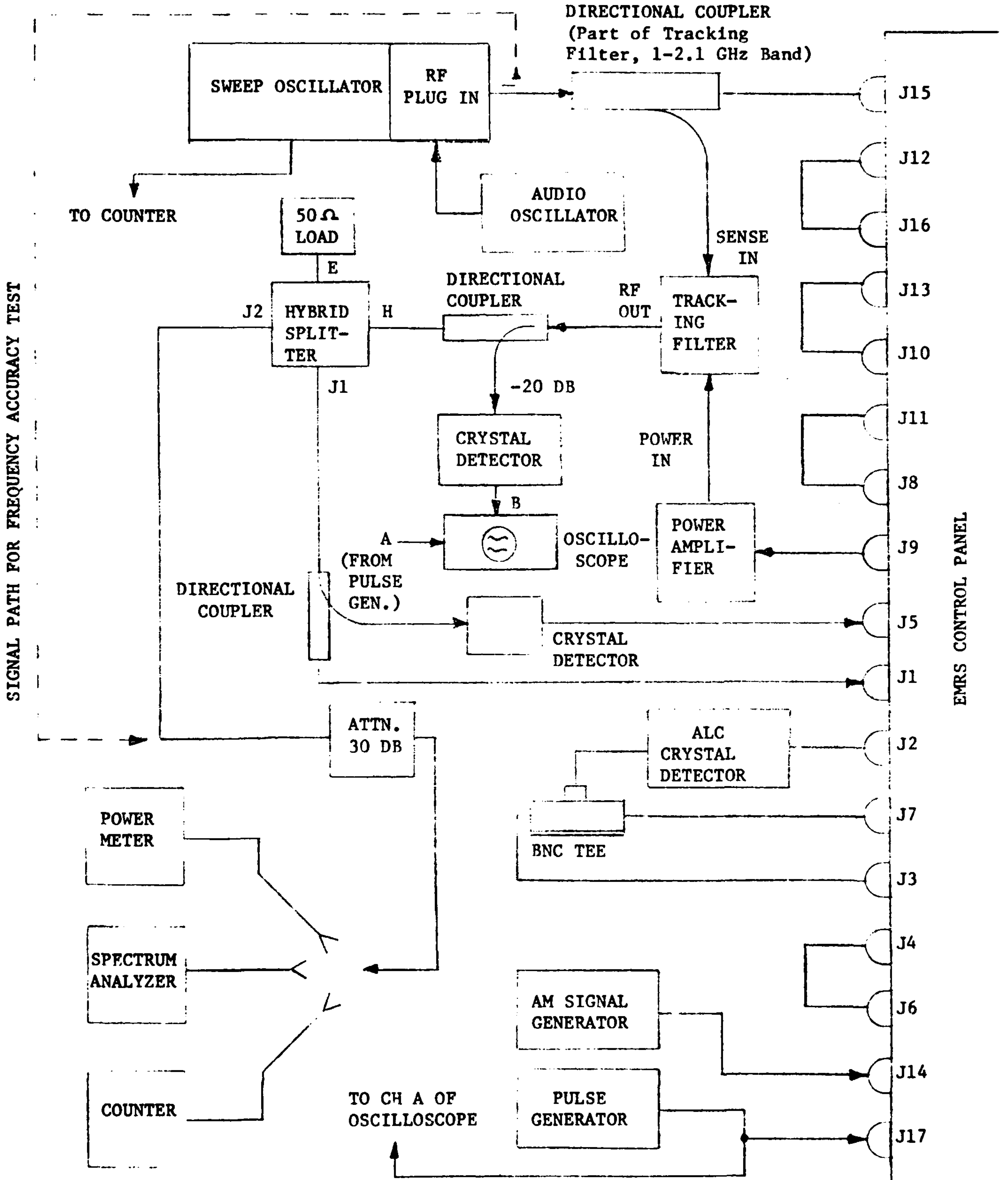
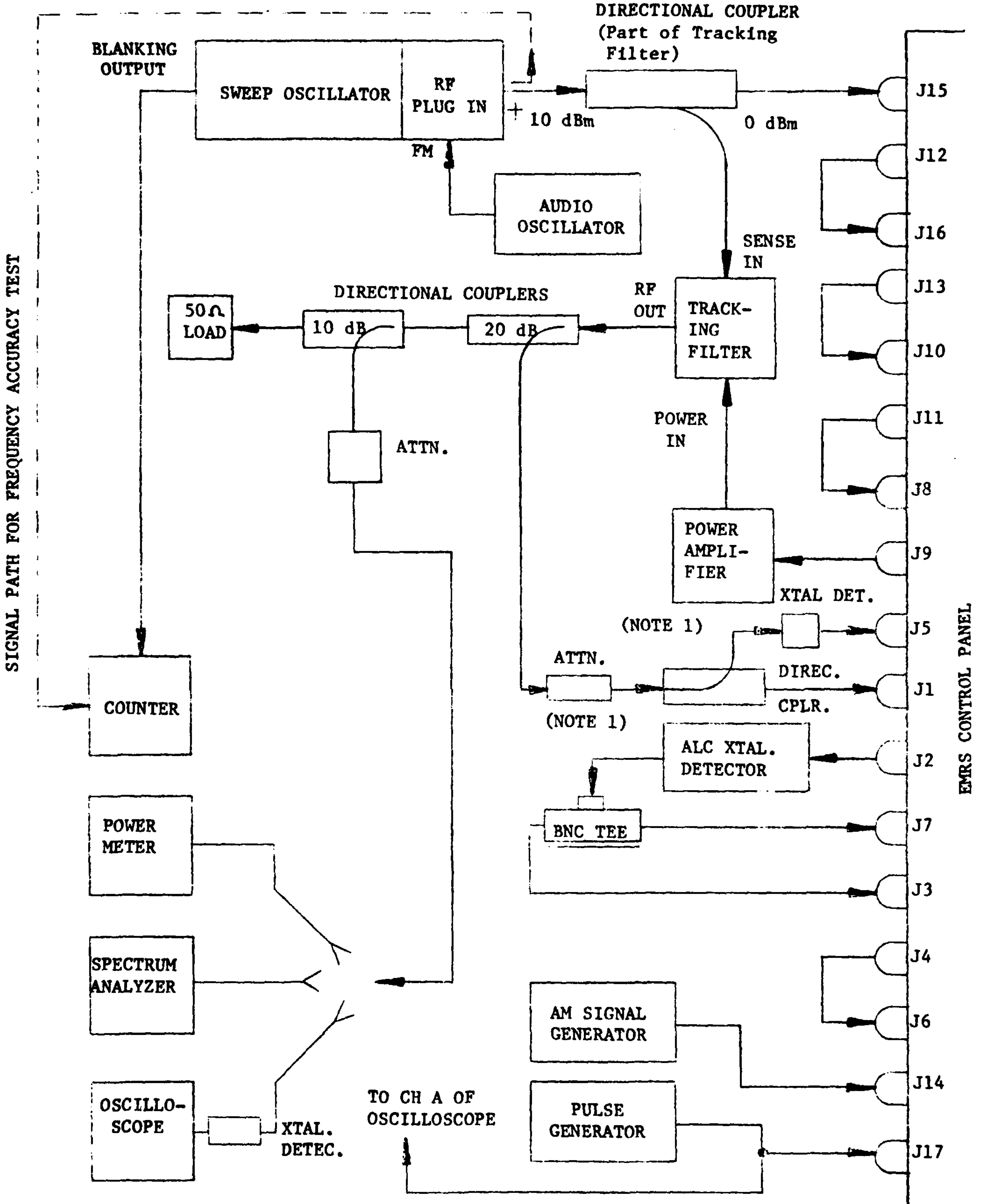


Figure 24. Test Setup, 30-60 MHz and 1-2.1 GHz Bands, Frequency Accuracy, Modulation Capabilities, Non-Radiated Power Output and Level Variations and Scan Rate Limits



NOTE 1 - Crystal detector and attenuator are not used in 12.4-18 GHz band.

Figure 25. Test Setup, 2.1-4 GHz and 12.4-18 GHz Bands, Frequency Accuracy, Modulation Capabilities, Non-Radiated Output and Level Variations and Scan Rate Limits

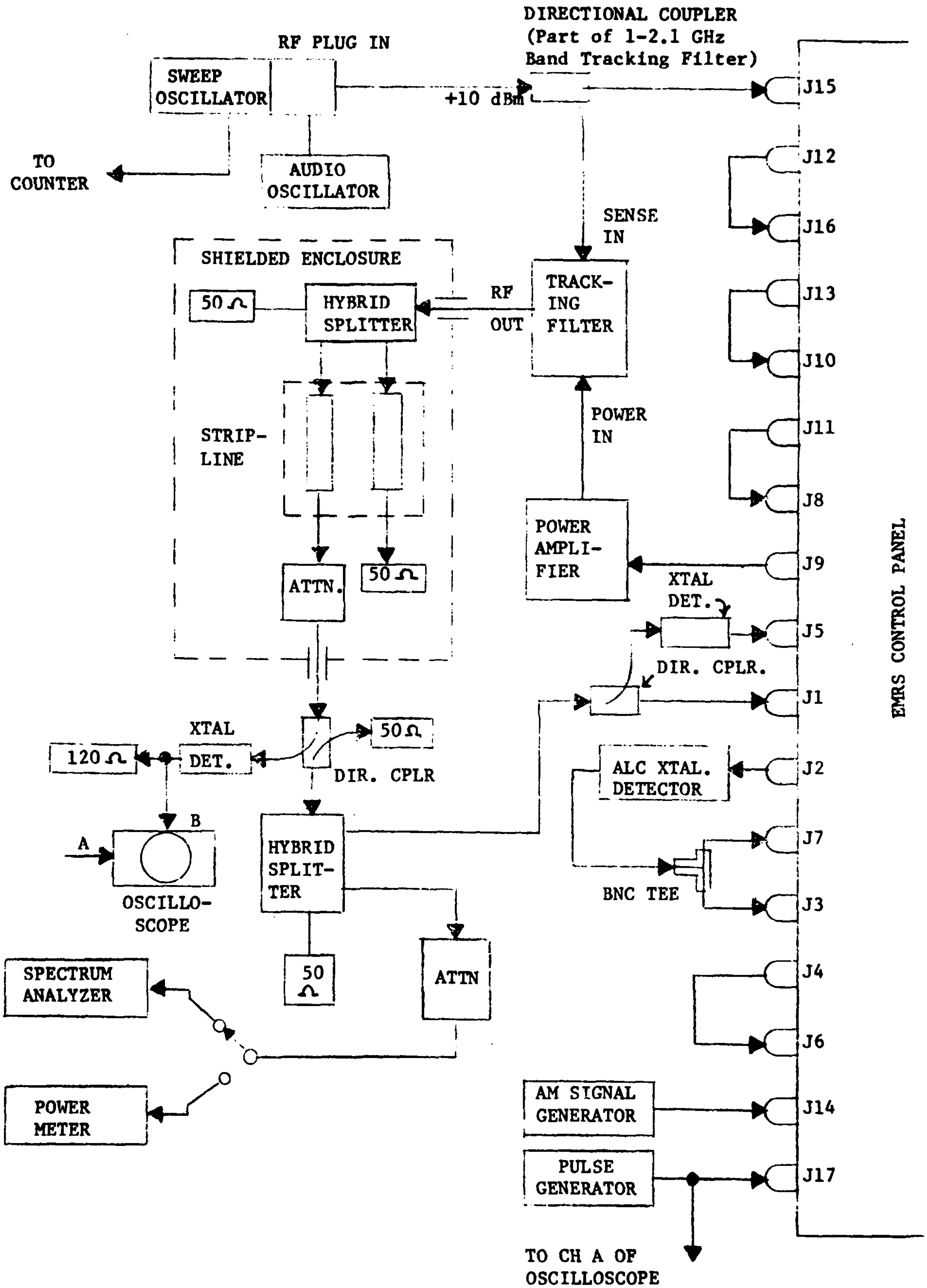
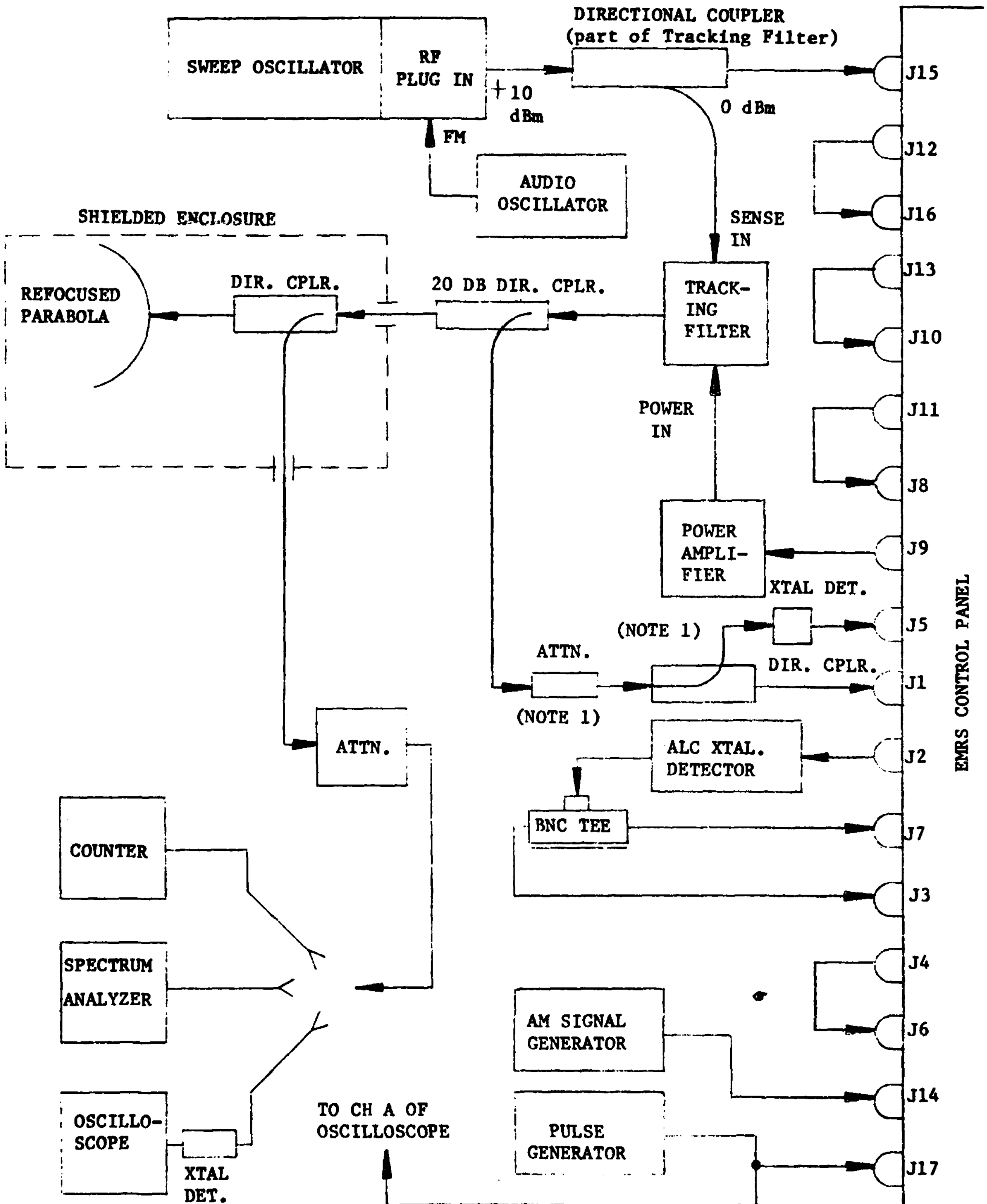


Figure 26. Test Setup, 30-60 MHz and 1-2.1 GHz Bands, Radiated Output and Power Level Variations



NOTE 1 - This detector, directional coupler and attenuator are not used in 12.4-18 GHz Band.

Figure 27. Test Setup, 2.1-4 GHz and 12.4-18 GHz Bands, Radiated Output and Power Level Variations

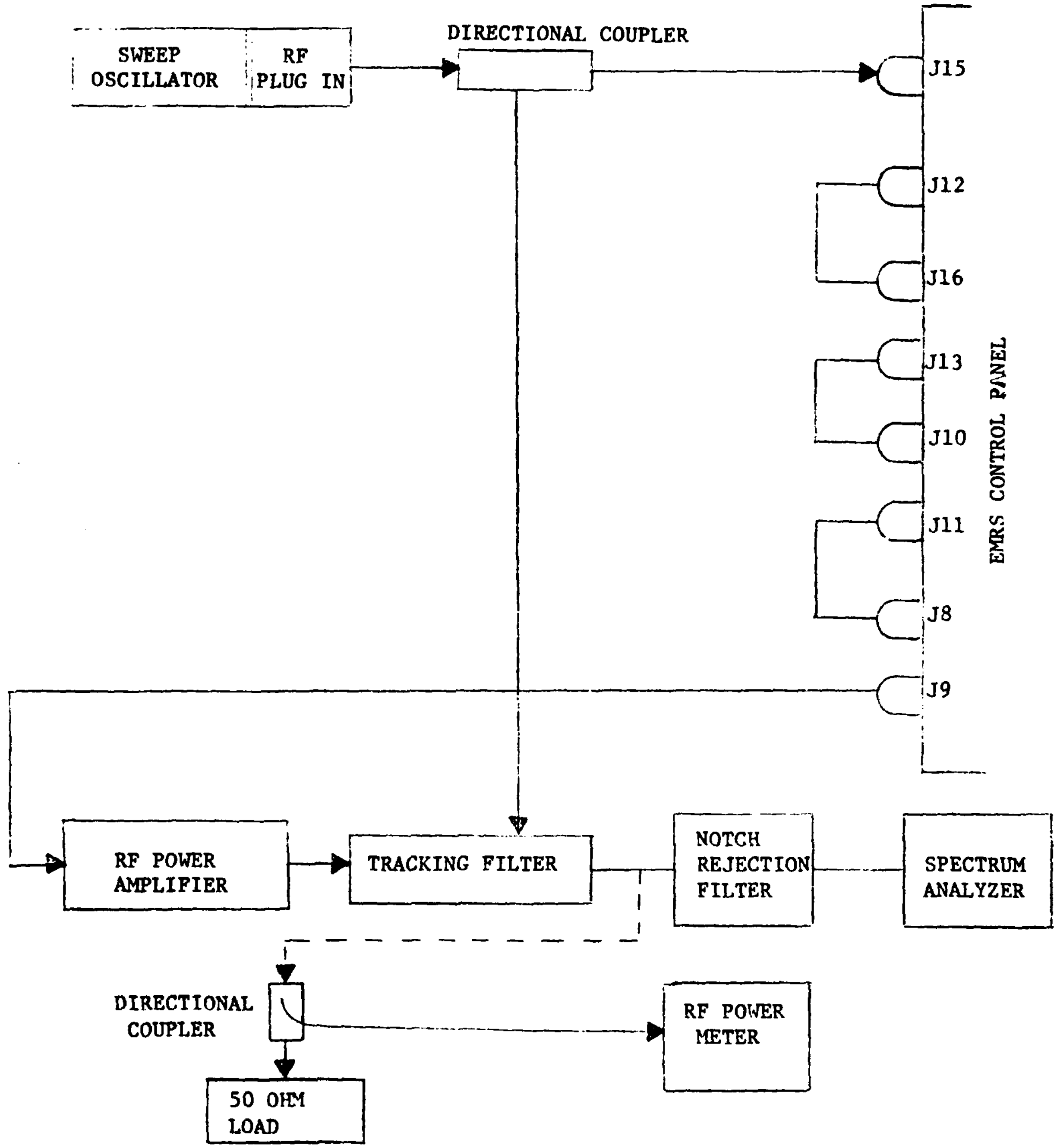


Figure 28. Test Setup, 30-60 MHz Band, Signal Purity

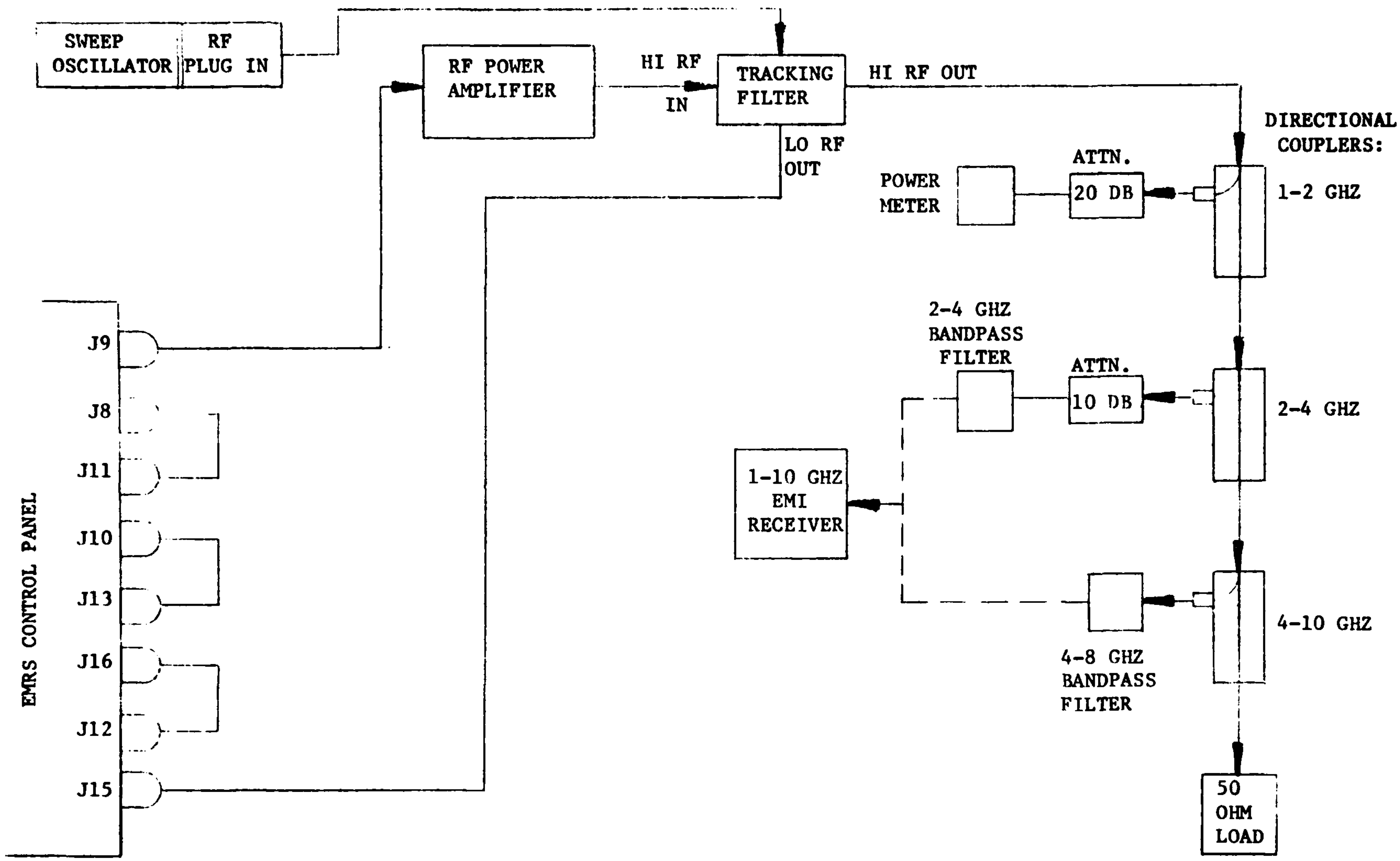


Figure 29. Test Setup, 1-2.1 GHz Band, Signal Purity

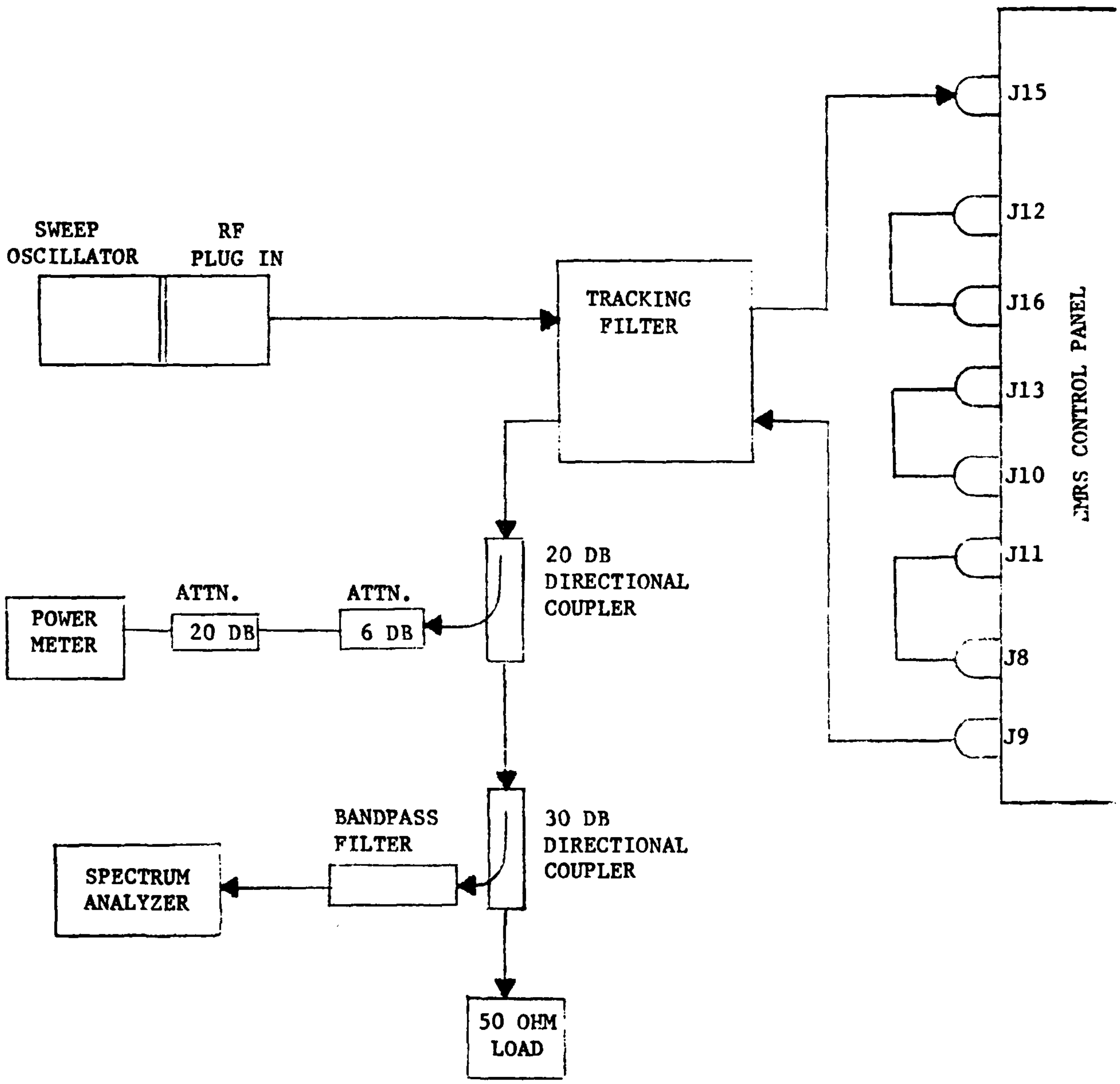


Figure 30. Test Setup, 2.1-4.0 GHz Band, Signal Purity

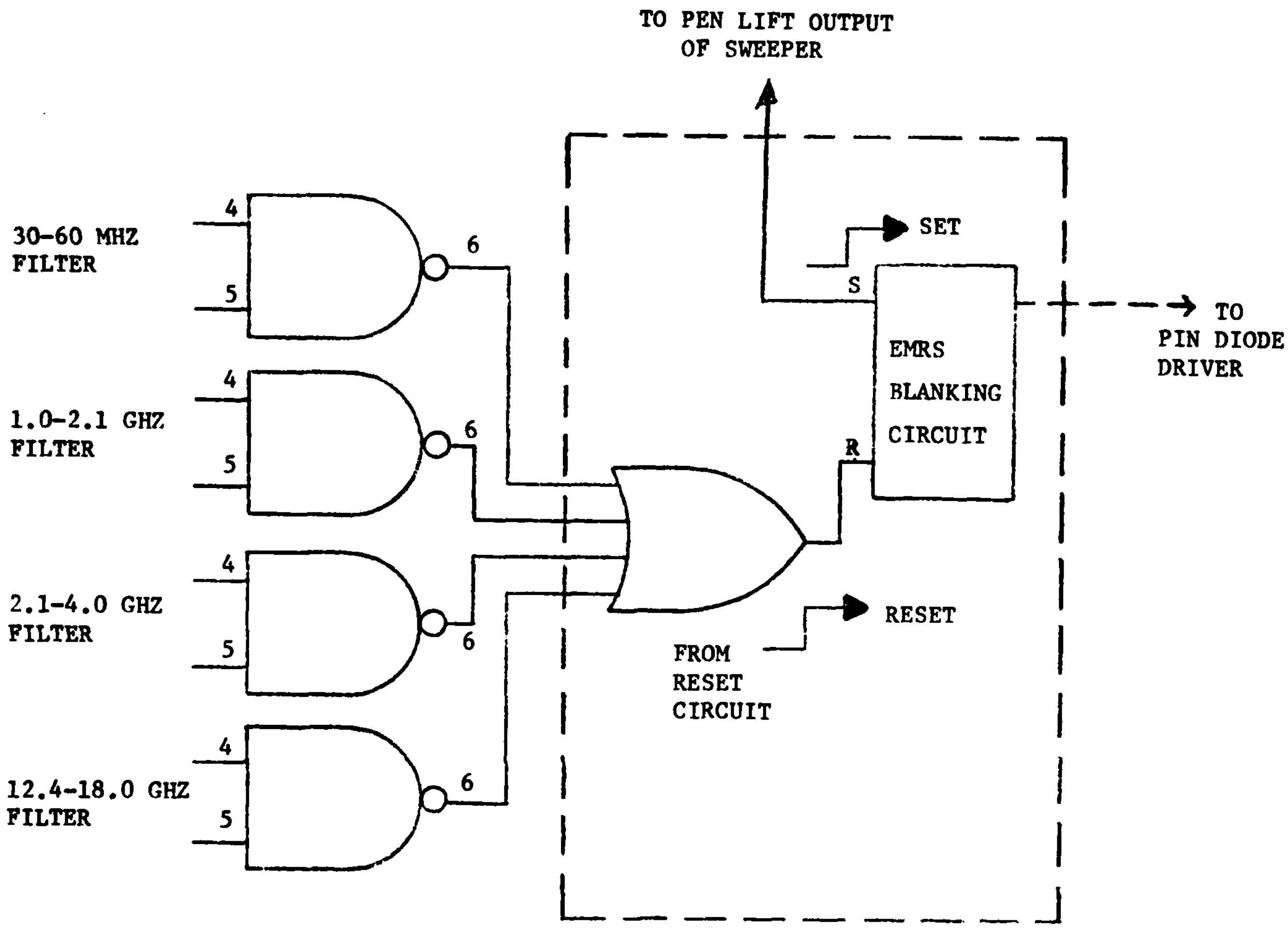


Figure 31. Proposed RF Blanking Logic

SECTION 9

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